Consultancy service for Preparation of Detailed Project Report for Construction of Elevated Corridors

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DETAILED PROJECT REPORT

Construction of Grade Separators at Pipeline Road from West of Chord Road to Outer Ring Road in Mahalakshmi Layout under Engineering, Procurement & Construction (EPC) Mode on Lumpsum, Turkey with allowable Price Escalation using Ultra High-Performance Fiber Reinforced Concrete (UHPFRC) - based structures including 10 years of maintenance

Volume-I
Main Report

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EXECUTIVE SUMMARY

E .1 INTRODUCTION

Bangalore has a total road network of 14,000 km with a road density of 8.2 km per square kilometer, significantly lower than cities like Delhi. This inadequate road infrastructure relative to the city's population and urban sprawl is a major contributor to persistent traffic congestion. The uncoordinated growth of urban areas without proportional infrastructure development has led to severe traffic bottlenecks. Roads in many newly developed areas remain narrow and poorly connected, creating critical mobility challenges during peak hours.

As of 2023, Bangalore had close to **10 million registered vehicles**, including over **7.5 million two-wheelers**. This rapid increase has outpaced the city's capacity to manage vehicular traffic, placing enormous strain on roads and junctions. An average of **1,530 new vehicles** are registered daily at Regional Transport Offices (RTOs). The Bengaluru Metropolitan Transport Corporation (BMTC) operates **6,340 buses** across **5,766 routes**, offering around **57,667 trips daily**. Although BMTC has introduced air-conditioned and electric buses to improve service, the current fleet is inadequate to fully meet the commuting needs of the growing population, resulting in increased dependence on private vehicles. The emergence of taxi-hailing services like **Ola** and **Uber** has increased the number of vehicles on the road. In 2022, Bangalore had **over 11 million registered vehicles**, including more than **251,000 taxis** (2020 figures). While these services improved accessibility, they have also added to overall congestion. The high vehicle count has also led to **severe air pollution**, especially from **diesel and two-stroke engines**. A 2016 study revealed that **36% of diesel vehicles** exceeded permissible emission standards. As of January 2019, the city had **1.94 lakh auto-rickshaws**, including over **25,000 two-stroke vehicles**, which were flagged for contributing disproportionately to air and noise pollution.

The city's attempts to manage congestion through **flyovers and one-way traffic systems** have shown only **moderate success**. While such interventions have provided temporary relief at certain choke points, their benefits have been short-lived due to induced demand, where improved travel times attract additional vehicles, quickly eroding capacity gains. These measures primarily address **point-specific bottlenecks** rather than providing **continuous, high-capacity corridors**, resulting in congestion simply shifting to adjacent intersections or approach roads. Moreover, the lack of parallel upgrades in the broader road network, limited integration with public transport, and inadequate facilities for non-

motorised transport have further reduced their long-term effectiveness. Rapid motorisation, coupled with urban sprawl and increasing trip lengths, has outpaced the incremental improvements offered by these solutions.

While long-term strategies such as expanding high-capacity public transport, ensuring last-mile connectivity, and developing non-motorised transport facilities are critical, capacity augmentation of the existing road network remains inevitable in the current context. Given the limited Right of Way (RoW) in densely built-up areas, the most practical and least disruptive solution is the development of elevated corridors along existing arterial routes. This "road over road" approach enables significant capacity enhancement, segregates through-traffic from local movement, and improves travel efficiency without the need for extensive land acquisition.

The present project has been conceptualized and developed in consultation with **Bengaluru Smart Mobility Infrastructure Limited (B-SMILE)**, the nodal agency under the newly constituted **Greater Bengaluru Authority (GBA)**, which has replaced the **Bruhat Bengaluru Mahanagara Palike (BBMP)** as the principal civic body overseeing major urban infrastructure. To address long-standing mobility challenges, GBA has initiated several high-priority projects including road widening, flyover construction, white-topping, and stormwater drain upgrades. As part of this infrastructure makeover, the Government of Karnataka has launched **B-SMILE**, a ₹7,000 crore mega programme aimed at providing seamless, sustainable, and future-ready mobility solutions for Bengaluru.

Within this framework, one of the most significant interventions is the construction of elevated corridors to enable fast, signal-free connectivity across the city. The present proposal, originally initiated under BBMP, is now being implemented by **BSMILE**. In line with this, BSMLIE has appointed **M/s Infra Support Engineering Consultants Pvt. Ltd.** through letter No. **BSMILE/SE/PR/40/2025-26 dated 14th August 2025** to provide **"Consultancy Services for Preparation of the Detailed Project Report (DPR) for the Construction of Elevated Corridors"**

a. **Proposed Elevated Corridor from Nagavara Junction - Ramakrishna Hegde Nagar Junction - Sampigehalli - Tirumenahalli - Bellahalli Junction - Bagalur Main Road.**

b. **Proposed additional link road to KIA, Elevated Corridor from Outer Ring Road - Hennur Main Road Junction to Bagalur Junction.**

c. **Proposed Elevated Corridor along Tannery Road from Madhava Mudaliyar Road to Nagavara Junction.**

d. **Proposed Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout).**

e. **Construction of Grade Separator at Kempegowda Circle Old Yelahanka.**

The Report exclusively discusses in detail the proposal for the Elevated Corridor from West of Chord Road to Outer Ring Road. The project corridor traverses one of the busiest urban environments in India, characterized by rapid growth in vehicular population, constrained right of way, and recurring congestion at critical junctions. Unlike conventional highway upgradation works in rural areas, this initiative is entirely urban, requiring careful integration of elevated structures with **existing roadways, utilities, metro corridors, and built-up urban fabric**.

The proposals have been formulated with an emphasis on **minimum land acquisition, reduction of social impacts, and optimization of traffic dispersal at junctions**. Based on stakeholder consultations and technical analysis, were developed for evaluation:

- **Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC)** Superstructure with Strut-and-Tie Box Sections (suitable for longer 50 m spans).

Proposed Elevated corridors alignment passes through densely developed corridors and critical institutional/commercial zones, such as West of Chord Road via pipe line road, where the traffic demand far exceeds existing capacity. The corridor is expected to provide a **continuous, signal free & east west linkage**, directly addressing the chronic problem of congestion in Bengaluru's arterial network.

Accordingly, the **Draft Detailed Project Report (DDPR)** has been prepared, incorporating **engineering designs, cost estimates as per PWD Karnataka SoR 2023–24 (Bengaluru Circle), and comparative analysis of superstructure alternatives**. The project development has thus been undertaken with the clear intent of delivering a **technically robust, socially responsive, and environmentally sustainable mobility solution** for the city.

E .2 PROJECT OVERVIEW

Project alignment improvement proposal comprises the design of elevated corridor aimed at strengthening the road network, easing congestion, and improving mobility in the

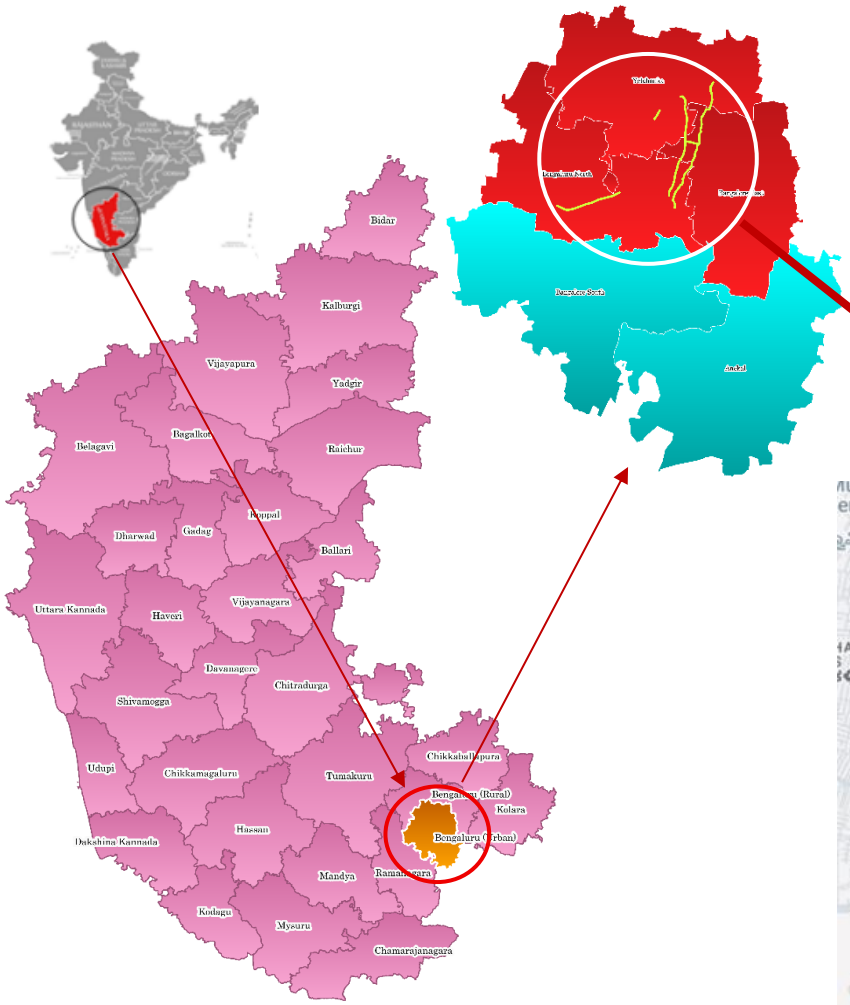
northern and eastern parts of Bengaluru. The project proposal includes Construction of Elevated Corridor from **West of Chord Road to Outer Ring Road Corridor (2.20 km)**, extending from West of Chord Road (Ch. 0+000) to Outer Ring Road (Ch. 2+850) via Mahalakshipuram, Nagapura, and Basaveshwaranagar, where improvements are confined from 0+000 to Ch. 2+200 section, owing to an ongoing grade separator construction; Together, these corridors provide seamless grade-separated linkages between major arterial routes and peripheral growth areas, reducing travel delays and enhancing accessibility to emerging urban and regional hubs.

Table E.1 : Details of Project Corridor

Sl No	Road Stretch	Length as Per ToR, Km	Length as Per Site in Km
1	"Preparation of Detailed Project Report (DPR) for Construction of Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout).	4.50	2.85
	Total Project Corridor Length, Km	4.50	2.85

The location of the project stretch is shown below:

Location of Project Road



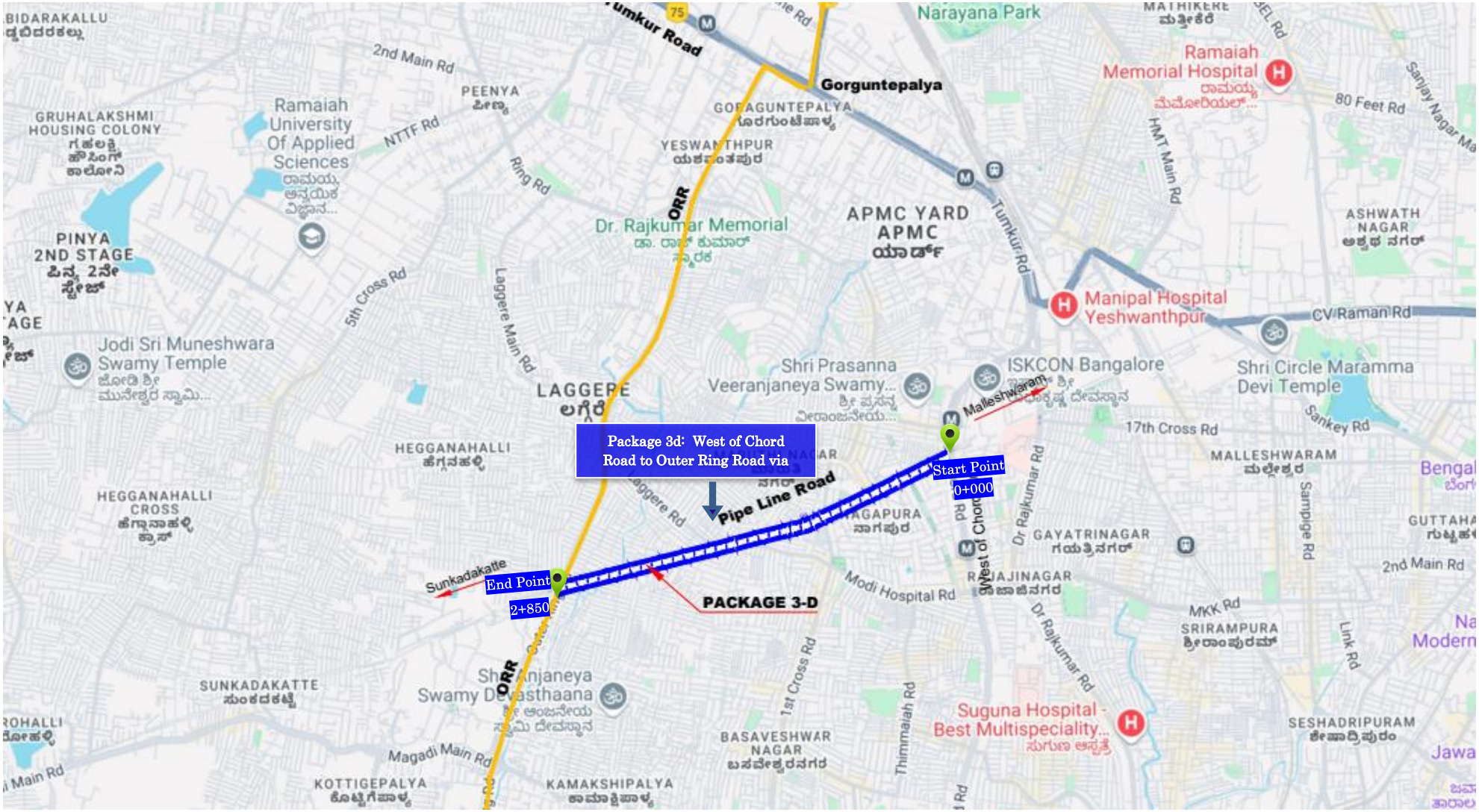
E 2.1 Key features of project

Table E.2 : Key features of West of Chord Road to Outer Ring Road via Pipeline Road

<table>
<tr><th>Sl No</th><th>Attributes</th><th>Details</th></tr>
<tr><td>1</td><td>Origin - Destination</td><td>West of Chord Road to Outer Ring Road via Pipeline Road
Start point: 13°00'21.5"N 77°32'54.7"E
End point: 12°59'58.1"N 77°31'46.2"E</td></tr>
<tr><td>2</td><td>Via</td><td>Via Mahalakshipuram, Nagapura, and Basaveshwaranagar.</td></tr>
<tr><td>3</td><td>Existing Carriageway</td><td><table><tr><th>Lane</th><th>Length RHS</th><th>Length LHS</th></tr><tr><td>2 Lane (Flexible)</td><td>2.050</td><td>1.66</td></tr><tr><td>4 Lane (Flexible)</td><td>0.15</td><td>0.54</td></tr><tr><td>Total Length in km</td><td>2.200</td><td>2.20</td></tr></table></td></tr>
<tr><td>4</td><td>Service lanes and slip roads</td><td>-</td></tr>
<tr><td>5</td><td>Shoulder</td><td>Varying Width
LHS: 1m to 3.5m
RHS: 0.6m to 4.7m -</td></tr>
<tr><td>6</td><td>Condition of existing pavement</td><td>Good to fair</td></tr>
<tr><td>7</td><td>Right of way</td><td>Typically, 9.4 to 45 m along the stretch</td></tr>
<tr><td>8</td><td>Land use along project road</td><td>The proposed alignment passes through a dense urban corridor with mixed land use, including high-density residential areas, commercial zones, major institutional establishments and recreational spaces.</td></tr>
<tr><td>9</td><td>Traffic on the stretch</td><td>Predominantly composed of passenger vehicles, including cars, two-wheelers, and auto-rickshaws, with minimal heavy vehicle movement.</td></tr>
<tr><td>10</td><td>Toll infrastructure</td><td>Nil</td></tr>
<tr><td>11</td><td>Terrain</td><td>The alignment passes through relatively flat terrain with slight undulations in elevation, typical of metropolitan topography.</td></tr>
<tr><td>12</td><td>Structures along stretch</td><td>Nil</td></tr>
</table>

Sl No	Attributes	Details
Other Details		
13	User amenities along stretch	7 bus bays
14	Key utilities in the proposed RoW	1. Water/Sewer/Storm Water/etc. 2. BESCOM/KPTCL/HT/LT/Transformer etc. 3. Canal/Drain Irrigation pipe etc. 4. OFC Cable
15	Forest Stretches along RoW	Nil
16	ROB/RUB	Nil
17	Other clearance related aspects	Nil

Key plan of existing project road



E .3 TRAFFIC DEMANDS ON PROJECT ROAD

Comprehensive traffic volume counts (TVCs) were conducted at strategic locations along the Project Impact Zone for Proposed elevated corridors. The list of traffic survey locations is given below.

Table E.3 : Traffic Survey Schedule

Sl. No	Station No.	Location Name	Date and Duration
Classified Traffic Volume Count			
1	TVC 01	Near Shiva Temple, West of Chord Road to Outer Ring Road via Pipeline Road	12-08-2025

Classified traffic data were collected for both directions and analyzed to determine the prevailing traffic composition, peak-hour traffic volumes, and the corresponding performance indicators

Table E.4 : Summary of Traffic Analysis

Type	Mode	West Chord Road to Outer Ring Road	Outer Ring Road to West Chord Road	Both Directions
Passenger	Two-Wheeler	9619	13471	23090
	Auto Rikshaw	1336	1715	3051
	Car/ Jeep / Taxi	6196	9727	15923
	Mini Bus	0	0	0
	Std Bus	80	235	315
Goods	Mini LCV	0	0	0
	LCV	324	678	1002
	2 Axle	104	105	209
	3 Axle	66	66	132
	MAV	32	33	65
Tractor	Agr. Tractor	0	0	0
	Agr. Tractor Trailer	0	0	0
Slow MovingVehicle		0	0	0
Total Vehicles		**17757**	**26030**	**43787**
Total PCUs		**17156**	**25175**	**42332**

The capacity assessment carried out at classified TVCs along the alignment TVC-01 (near Shiva Temple), shows that peak-hour volumes are already at or very close to the practical planning capacity of a 4-lane urban arterial elevated facility (≈3,600 PCU/h two-way) in the opening year (2025). Computed V/C ratios for 2025 are approximately 0.95 (TVC-01), deteriorating rapidly under the conservative 5% annual traffic growth assumption. By the near-term horizon all three TVCs are projected to operate at LOS-E/F, with peak-period queuing and breakdown expected at critical merge/weave locations.

The corridor traverses densely built urban sectors with frequent major and minor junctions and short inter-junction spacings (varied from a few hundred metres to a few kilometres). Isolated grade separators or local capacity treatments at single junctions are unlikely to provide lasting relief because they transfer congestion downstream and typically require substantially larger ROW and staging impacts in a constrained urban setting. By contrast, a continuous, access-controlled elevated corridor provides through-capacity by segregating long-distance and through traffic from local at-grade movements, preserves operational efficiency on the surface network, and minimizes repeated ROW widening and property impacts.

Accordingly, the DPR recommends implementation of an access-controlled elevated corridor as the preferred capacity-augmentation strategy. Key design and operational measures to be included are: provision of auxiliary acceleration/deceleration lanes at ramp merges/diverges, optimized ramp spacing and ramp geometry to reduce weaving, shoulders for incident management, ITS/ITMS (CCTV, VMS, ramp-metering capability and incident detection), protected utility ducts to avoid frequent road reopening, and structural provision for staged future widening (allowing conversion to 3 lanes/dir or addition of auxiliary lanes at forecasted hotspots). These integrated measures are necessary to meet the design-year demand while maintaining acceptable service levels and safety in the highly constrained urban corridor.

Table E.5 : Cardinal Years Projected Traffic

Cardinal Year	Cardinal Years Traffic, (PCU)
	TVC 01
Growth Rate, %	5%
2025	42,332

Cardinal Year	Cardinal Years Traffic, (PCU)
	TVC 01
2028	53,904
2033	72,237
2038	87,805
2043	1,12,063
2048	1,43,024

Table E.6 : Capacity Analysis

Year	TVC 01	
	ADT (PCU/day)	V/C
2025	42,332	0.95
2028	49,004	1.10
2033	62,543	1.40
2038	79,822	1.78
2043	1,01,876	2.28
2048	1,30,022	2.91

E .4 PAVEMENT AND CORRIDOR SURVEYS

E 4.1 Pavement condition and distress seen

The overall pavement condition is Good to fair condition

Table E.7 : Condition survey of existing pavement

Pavement Distresses	Project Corridor
Potholes	1.00
Cracks	5.00
Patching	1.20
Ravelling	10.00
Settlement / Upheaval	0.00
Edge Break	0.00
Rutting	0.00

Pavement Distresses	Project Corridor
Bleeding	0.00
Good Condition	92.53

E .5 IMPROVEMENT PROPOSALS

E 5.1 Alignment

Project alignment improvement proposal comprises the design of elevated corridor aimed at strengthening the road network, easing congestion, and improving mobility in the northern and eastern parts of Bengaluru. The project proposal includes Construction of Elevated Corridor from **West of Chord Road to Outer Ring Road Corridor (2.20 km)**, extending from West of Chord Road (Ch. 0+000) to Outer Ring Road (Ch. 2+850) via Mahalakshipuram, Nagapura, and Basaveshwaranagar, where improvements are confined from 0+000 to Ch. 2+200 section, owing to an ongoing grade separator construction; Together, these corridors provide seamless grade-separated linkages between major arterial routes and peripheral growth areas, reducing travel delays and enhancing accessibility to emerging urban and regional hubs.

Table E.8 : Summary of Proposed Improvement along the Project Corridor

Sl.	Parameter	West of Chord Road to Outer Ring Road
1	Length of Main Carriageway	1580
2	Length of Roundabout (Junctions)	
3	Length of Split CW Section	
4	Length of Ramps Section (MCW)	400
5	Length of Curved Section	
6	Length of Taper section	
7	Length of Down ramp	
8	Length of up ramp	
9	Length of Viaduct ramp (Up and Down)	
10	Length of Up & Down ramp	
11	Length of Connecting Road	
	Total length of Improvement-Elevated	**1980**
	Total length of Improvement-At_grade	**2100**

E 5.2 Proposed Cross Sections

Lane width, shyness, median width and overall width of each cross section proposed are derived from IRC: SP: 90 and IRC: 86, ensuring compliance with design standards for urban elevated facilities. The adopted widths are as follows:

Elevated Road:

- The lane width shall be 3.5 m
- The shyness shall be 0.5 m
- Paved Shoulder shall be 1.50m
- The median width shall be 0.610m for New Jersey Crash barrier.
- The total width of 4 lane elevated corridor is will be 19.61m

At Grade Road:

- The lane width shall be 3.0/3.5 m
- The shyness shall be 0.25/0.5 m
- The service lane shall be 5.5/7.5 m

Accordingly, the elevated corridor have been planned as 4-lane access-controlled facilities, with configuration tailored to projected traffic flows and location-specific requirements of entry and exit ramps. The above standards will be consistently applied during detailed geometric design to ensure operational efficiency, safety, and compliance with IRC norms

E 5.3 Project Proposals

The project proposal comprises elevated corridor strategically planned to enhance and improve access to the airport influence zone while easing congestion on parallel arterial routes in Bengaluru. The West of Chord Road to ORR Corridor (2.20 km) are planned as short but critical interventions, integrating with ongoing works and major junctions to streamline traffic flow. Collectively, these interventions are expected to reduce conflicts at major intersections, provide signal-free travel, and establish a high-capacity elevated network complementing the city's arterial and sub-arterial road system.

The elevated carriageway has been designed as a 4-lane facility with 3.5 m lanes, 0.5 m shy distance, and 1.5 m paved shoulders, ensuring adequate operational safety. At-grade lanes are standardized at 3.0 m width with 0.25/0.5 m shy distance, reflecting Tender SURE and BBMP urban standards. Horizontal alignment has generally adhered to design speeds of 60/80 km/h with minimum curve radii of 150 m, while constrained locations

necessitated reduced radii, with adequate design justification. Vertical geometry has been optimized to maintain safe sight distances and operational efficiency.

To balance accessibility with minimal land acquisition, ramps of 4.5 m width with protective crash barriers are provided only at strategically required locations, coordinated with tunnel entry/exit points. Restoration measures include provision of a 1.8 m minimum footpath-cum-drain wherever land available/required, smoothened junction entry/exit curves, modern street lighting, signage, and pavement markings, thereby improving local-level traffic flow.

The project incorporates multiple superstructure systems tailored to site conditions and span requirements:

- PSC I-Girders for regular spans,
- PSC Box Girders for medium spans,
- UHPFRC Strutted Box Sections for high durability and reduced depth,
- Steel Composite/ Girders for obligatory longer spans and rail/metro crossings.

UHPFRC Superstructure were specifically developed for cost:

UHPFRC superstructure with strut-and-tie box sections, enabling longer spans with fewer piers, ideal for constrained urban junctions and crossings.

The cost implications using PWD Karnataka SoR 2023–24 (Bengaluru Circle). For the proposed elevated corridor, 50 m UHPFRC strut-and-tie box spans were evaluated, with the 50 m UHPFRC span system recommended owing to its superior structural efficiency, reduced pier footprint in constrained urban conditions, and enhanced durability.

The corridor integrates a comprehensive suite of safety and serviceability features including New Jersey crash barriers (0.61 m median), High Containment Crash Barrier, edge protection systems, utility corridors/ducts at 500 m spacing to prevent repeated road cutting, and ITMS (Intelligent Traffic Management Systems). Pedestrian safety is addressed through redesigned bus stops (at disturbed location), with noise barriers proposed at sensitive urban stretches. The combined implementation of the Elevated Corridors will provide a high-capacity, signal-free arterial linkage across north–south as well as east–west sectors across the northern and eastern zones of the Bengaluru. With robust geometric standards, carefully designed ramps, integrated at-grade improvements, hybrid structural systems, and advanced safety and ITMS provisions, the project ensures

long-term durability, congestion relief, and sustainable urban mobility. It is strongly recommended to proceed with the current proposal, adopting a judicious mix of 35 m spine and wing spans and 50 m UHPFRC spans, thereby balancing economy, constructability, and service performance in line with forecasted traffic demand.

E 5.4 Pavement

For the project improvement, Service Road and Approach Ramps are proposed with Flexible pavement. The Design of flexible Pavement is made based on IITPAVE Analysis as explained in IRC 37-2018.The design of White Topping is made as per IRC SP 76-2015 "Guidelines for Conventional and Thin White Topping".

Table E.9 : Proposed Flexible Pavement Composition for Service Roads and Approach and Entry / Exit Ramps

Sl No	Description	Values
1	**Design Traffic, msa**	**20**
2	Allowable Maximum Horizontal Tensile strain below BT Layer, micro strain	225.4
3	Allowable Vertical compressive strain above Subgrade, micro strain	301.9
	Pavement Layers	**Trial thickness, mm**
4	Bituminous Concrete (BC), mm	40
5	Dense Bituminous Macadam (DBM), mm	80
6	Wet Mix Macadam (WMM), mm	250
7	Granular Subbase (GSB), mm	200
8	**Total Pavement Crust Thickness, mm**	**570**
	IITPave Analysis Output	
9	Obtained Horizontal Tensile strain below BT Layer, Micro strain	225.3
10	Obtained Vertical compressive strain above Subgrade, Micro strain	239.4
11	**Design w.r.to Obtained Maximum Horizontal Tensile strain**	**Design is Safe**
12	**Design w.r.to Obtained Vertical compressive strain**	**Design is Safe**

E .6 DESIGN OF STRUCTURES

The proposed structural configuration for the project comprises a variety of arrangements, including single and divided decks, portal and single piers, and pile foundations, designed

with careful consideration of space constraints and traffic movement in urban environments. Given the corridor's location within a densely developed area, special attention has been paid to minimizing interference with at-grade traffic while ensuring structural efficiency and safety. Each section of the alignment has been meticulously studied through detailed topographic surveys and site assessments to determine optimal pier placements and structural systems. The structural solutions vary in terms of width, lane configuration, and deck type ranging from single-lane ramps to four-lane main alignments, with associated elements such as crash barriers, shoulders, kerb shyness zones, medians, and carriageways carefully dimensioned to suit the functional requirements of each segment.

Span configurations provided are 30 and 50 meters, utilizing a diverse range of superstructure types such as precast PSC I-girders, PSC box segments, strutted systems.

Table E.10 : Span configuration and type of superstructure

SL No.	Span Configuration	Type of Superstructure	Deck Width
1.	30.0	Precast PSC-I-Girder	19.61
2	50.0	UHPFRC Strutted Box	19.61m

E .7 PROJECT COST ESTIMATES

The project cost estimate has been prepared based on the scope of works for the proposed elevated corridor project,

Proposed Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout).

Super Structure proposal includes Ultra High-Performance Fiber Reinforced Concrete (UHPFRC) Superstructure: Comprising Strut-and-Tie Box Sections, offering enhanced durability, reduced maintenance requirements, and superior life-cycle performance.

The total project cost includes Construction Cost, Preliminaries & General Works, Maintenance During Construction, Land Acquisition and Utility Relocation Costs. A detailed breakup of costs, along with comparative estimates for the two alternatives, is presented in below table

Table E.11 : Summary of Cost Estimate

Sl. No.	Items	Amount (In Rs)
1	Excavation for foundation	14,48,637.94
2	Foundation	77,97,17,490.50
3	Substructure	24,23,60,735.67
4	Super structure	1,47,59,34,802.68
5	Re walls approaches	3,56,57,474.89
6	At-grade improvement	42,88,65,547.34
7	Lighting	1,81,73,365.74
8	Preliminaries and general works	6,25,71,678.27
	Sub Total -A	**3,04,47,29,733.03**
9	Design charges @ 1.00% (For the amount sl.No 1 to Sl.No 8)	3,04,47,297.33
10	Maintenance during construction	8,53,32,951.86
	Sub Total -B	**11,57,80,249.19**
11	Maintenance charges for stand alone projects like Bridges/Tunnels/Flyover work; The Contractor shall be paid at 0.25% of the contract price, each for the remaining period of 5 years on total of items as per MorTH LTR No: RW/NH-37010/4/2010-EAP (Printing) Vol-IV, Government of India, Minitry of Road Transport and Highways dated: 05.03.2019 at model agreement page no.76 under section 14.1D	
12	for first 5 years @ 0.25%	3,80,59,121.66
13	for 5-10 years @ 0.50%	7,61,18,243.33
	Sub Total -C	**11,41,77,364.99**
	Amount put to tender (APT- A+B+C), Rs.	**3,27,46,87,347.21**
	GST @ 18%	58,94,43,722.50
	Total Civil Cost, Rs.	**3,86,41,31,069.71**
i	Provision for Contingencies and Provision for Departmental Establishment Charges @ 1% on APT	3,27,46,873.47
ii	Provision for Independent Engineer / PMC @ 1.50% on APT (Including GST)	5,79,61,966.05
iii	Provision for Price escalation @ 5.0% for the 2nd year i.e., 0.5% of APT (Including GST)	9,66,03,276.74
iv	Provision or utility shifting at 8% of APT (Including GST)	30,91,30,485.58
v	Provision for Arboriculture/ Afforestation @ 0.50% on APT (Including GST)	1,93,20,655.35
vi	Land Acquisition Cost including structures/TP	50,99,05,673.10
vii	Miscellenous and other Department Deposits	2,00,000.00
	Total Project Cost	**4,89,00,00,000.00**

E .8 DISCUSSION AND CONCLUSIONS

The proposed Elevated Corridor form a strategically significant intervention to decongest Bengaluru's arterial network by providing a continuous, access-controlled facility. The corridor will reduce travel time, improve traffic dispersal, enhance road safety, and lower vehicle operating costs, fuel use, and emissions while improving the efficiency of public transport. Beyond mobility, it is expected to catalyze economic growth, stimulate commercial activity, generate employment, and improve access to workplaces, markets, institutions, and healthcare. With integrated safety and community features such as footpaths, guardrails, crash barriers, drainage, LED lighting, landscaping, and pedestrian facilities, the project will improve both commuter convenience and public safety, thereby transforming mobility patterns, promoting sustainable growth, and enhancing Bengaluru's competitiveness as a global innovation hub.

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CHAPTER 1. INTRODUCTION

1.1 PROJECT BACKGROUND

Bengaluru, also known as **Bangalore**, is the capital and largest city of the southern Indian state of Karnataka. As per the 2011 census, the city had a population of 8.4 million, making it the third most populous city in India and the most populous in South India (the current population is estimated between 1.3 Cr to 1.6 Cr, based on different sources and estimation). It is located near the center of the Deccan Plateau, at a height of 900 m (3,000 ft) above sea level. The city is known as India's "Garden City", due to its parks and greenery.

As of 2023, the metropolitan area had an estimated GDP of $359.9 billion, and is one of the most productive metro areas of India. The city is a major center for information technology (IT), and is consistently ranked amongst the world's fastest growing technology hubs. It is widely regarded as the "Silicon Valley of India", as the largest hub and exporter of IT services in the country. Manufacturing is a major contributor to the economy and the city is also home to several state-owned manufacturing companies. Bengaluru also hosts several institutes of national importance in higher education.

Bengaluru has an extensive road network with about 14,000 km of roads as of 2024. The 10 km long Inner Ring Road connects Koramangala with Indira Nagar. The Outer Ring Road is a 60 km long peripheral road, developed between 1996 and 2002. The Peripheral Ring Road of 74 km, semi-circular road, connecting major arterial roads is in the proposal. The M G Road is the major arterial road in the central business district. Bengaluru is part of the Golden Quadrilateral highway network, and lies on the Chennai–Mumbai line. The National Highways that connect to the city include: NH-44, NH-48, NH-275, NH-75, NH-648, and NH-948. The Bengaluru–Mysuru Expressway, operational since March 2023, connects the city with Mysuru. The Bengaluru-Chennai Expressway is under construction since August 2019. Two other expressways - Pune - Bengaluru Expressway and Nagpur – Hyderabad - Bengaluru Expressway - have been proposed.

Bangalore, is now classified as a mega city. The last five decades have been a period of rapid growth for Bangalore with a proliferation of multinational companies choosing to locate their operations in the city and its environs in industrial products, consumer durables and more recently information technology.

Bengaluru holds a unique position on the global map, serving as a nucleus for business, education, science, and information technology, and is globally recognized as India's foremost technology hub and "Silicon Valley of India." Over the past five decades, the city has witnessed unprecedented urbanization and explosive population growth, driven by its thriving IT, biotechnology, aerospace, and startup ecosystems. This rapid transformation has propelled Bengaluru into a leading centre for research, innovation, and high-value industries, attracting a diverse talent pool from across the country and abroad. However, the city's transition from a once serene, garden filled urban settlement to a bustling metropolitan agglomeration has brought significant challenges, including severe traffic congestion, pressure on civic infrastructure, environmental stress, and spatial expansion far beyond its core. As Bengaluru continues to expand both demographically and economically, strategic infrastructure planning particularly in mobility and transport has become critical to sustain its role as a global economic powerhouse while ensuring quality of life for its residents.

With an overall rapid increase in population coupled with the seemingly irreversible flow of people from rural to urban areas, Bangalore has been acquiring unplanned and uncontrolled squatter settlements from all over the country. The glass walled computer – ready office complexes, exclusive shopping malls and entertainment facilities that rival the best in the country contrast with the dense squatter settlements and their very poor services in central areas of the city.

Since, Bangalore has a total road network of **14,000 km** with a road density of **8.2 km per square kilometer,** significantly lower than cities like Delhi. This inadequate road infrastructure relative to the city's population and urban sprawl is a major contributor to persistent traffic congestion. The uncoordinated growth of urban areas without proportional infrastructure development has led to severe traffic bottlenecks. Roads in many newly developed areas remain narrow and poorly connected, creating critical mobility challenges during peak hours.

Bruhat Bengaluru Mahanagara Palike (BBMP) was the administrative body responsible for civic amenities and infrastructural assets of the Greater Bengaluru metropolitan area. It is the fourth largest Municipal Corporation in India and was responsible for an area of 741 km2. Its boundaries expanded more than 10 times since the 1950s. BBMP was replaced by the Greater Bengaluru Authority on 15 May 2025; however, the BBMP will continue to administer the city until the new Authority is fully operational.

Its roles and responsibilities included the "orderly development of the city" zoning and building regulations, health, hygiene, licensing, trade and education, as well as quality of life issues such as public open space, water bodies, parks and greenery.

Bengaluru Smart Mobility Infrastructure Limited (B-SMILE) is a **Special Purpose Vehicle (SPV)** established by the Government of Karnataka with a capital corpus of ₹7,000 crore (90% GoK, 10% BBMP) to plan, finance, and implement large-scale mobility and transport infrastructure projects across the Bengaluru Urban district. Governed by a board chaired by a full-time IAS officer and comprising key civic officials and infrastructure experts, B-SMILE has taken over major projects earlier handled by BBMP, including flyovers, underpasses, elevated corridors, tunnel roads, and roads along stormwater drains, while BBMP continues routine civic works. Operating on the lines of MMRDA, B-SMILE's mandate covers strategic, high-impact projects such as the proposed 40 km tunnel road network, large flyover packages, and landmark infrastructure aimed at decongesting the city and improving connectivity. Notably, a ₹17,780 crore, 16.7 km twin-tunnel project from Hebbal to Silk Board is under global tendering as part of its flagship initiatives. By consolidating high-value urban mobility projects under a single entity, B-SMILE is positioned to deliver faster, more efficient, and technically robust infrastructure solutions for Bengaluru's growing transport demands.

Transport in Bengaluru consists of several intracity commute modes such as BMTC buses, Namma Metro rail services, taxis and auto rickshaws, as well as several intercity forms of transport: Government operated KSRTC, NWKRTC, KKRTC, other states RTC buses, Private bus operators, trains, and flights.

As of 2023, Bangalore had close to **10 million registered vehicles**, including over **7.5 million two-wheelers**. This rapid increase has outpaced the city's capacity to manage vehicular traffic, placing enormous strain on roads and junctions. An average of **1,530 new vehicles** are registered daily at Regional Transport Offices (RTOs). The Bengaluru Metropolitan Transport Corporation (BMTC) operates **6,340 buses** across **5,766 routes**, offering around **57,667 trips daily**. Although BMTC has introduced air-conditioned and electric buses to improve service, the current fleet is inadequate to fully meet the commuting needs of the growing population, resulting in increased dependence on private vehicles. The emergence of taxi-hailing services like **Ola** and **Uber** has increased the number of vehicles on the road. In 2022, Bangalore had **over 11 million registered vehicles**, including more than **251,000 taxis** (2020 figures). While these services improved accessibility, they have also added to overall congestion. The high vehicle count has also

led to **severe air pollution**, especially from **diesel and two-stroke engines**. A 2016 study revealed that **36% of diesel vehicles** exceeded permissible emission standards. As of January 2019, the city had **1.94 lakh auto-rickshaws**, including over **25,000 two-stroke vehicles**, which were flagged for contributing disproportionately to air and noise pollution.

The city's attempts to manage congestion through **flyovers and one-way traffic systems** have shown only **moderate success**. While such interventions have provided temporary relief at certain choke points, their benefits have been short-lived due to induced demand, where improved travel times attract additional vehicles, quickly eroding capacity gains. These measures primarily address **point-specific bottlenecks** rather than providing **continuous, high-capacity corridors**, resulting in congestion simply shifting to adjacent intersections or approach roads. Moreover, the lack of parallel upgrades in the broader road network, limited integration with public transport, and inadequate facilities for non-motorised transport have further reduced their long-term effectiveness. Rapid motorisation, coupled with urban sprawl and increasing trip lengths, has outpaced the incremental improvements offered by these solutions.

While long-term strategies such as expanding high-capacity public transport, ensuring last-mile connectivity, and developing non-motorised transport facilities are critical, capacity augmentation of the existing road network remains inevitable in the current context. Given the limited Right of Way (RoW) in densely built-up areas, the most practical and least disruptive solution is the development of elevated corridors along existing arterial routes. This "road over road" approach enables significant capacity enhancement, segregates through-traffic from local movement, and improves travel efficiency without the need for extensive land acquisition.

In this context, the **Greater Bengaluru Authority (GBA)** has replaced the **Bruhat Bengaluru Mahanagara Palike (BBMP)** as the principal civic body overseeing urban infrastructure. To address long standing mobility challenges, GBA has initiated several infrastructure projects, including road widening, flyover construction, and white-topping works. To streamline project execution, **Bengaluru Smart Mobility Infrastructure Limited (B-SMILE)** has been established under GBA to take charge of key mobility and transport projects.

Bangalore is going through a big infrastructure makeover in 2025. The Karnataka government has launched B-SMILE, a ₹7,000 crore mega boost to improve the city's roads, flyovers, and drains. This is one of the largest upgrades in recent years.

One such major initiative is the construction of **elevated corridors** to provide fast, seamless connectivity across the city. The present proposal originally initiated under BBMP is now being implemented by **B-SMILE**. In line with this, **B-SMILE** has appointed **M/s Infra Support Engineering Consultants Pvt. Ltd.** through letter No. **BSMILE/SE/PR/40/2025-26 dated 14th August 2025** to provide **"Consultancy Services for Preparation of the Detailed Project Report (DPR) for the Construction of Elevated Corridors"**

a. **Proposed Elevated Corridor from Nagavara Junction - Ramakrishna Hegde Nagar Junction - Sampigehalli - Tirumenahalli - Bellahalli Junction - Bagalur Main Road.**
b. **Proposed additional link road to KIA, Elevated Corridor from Outer Ring Road - Hennur Main Road Junction to Bagalur Junction.**
c. **Proposed Elevated Corridor along Tannery Road from Madhava Mudaliyar Road to Nagavara Junction.**
d. **Proposed Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout).**
e. **Construction of Grade Separator at Kempegowda Circle Old Yelahanka.**

The report exclusively discusses in detail the proposal for the Elevated Corridor from West of Chord Road to Outer Ring Road. B-SMILE has envisioned preparation of DPR with main objectives as follows.

1.2 OBJECTIVE OF THE PROJECT

The primary objective of the Elevated Corridor Project in Bengaluru is to develop an elevated road network aimed at significantly decongesting the city's surface roads, enhancing traffic flow, reducing travel time, and improving overall connectivity across key corridors within the metropolitan area.

This objective aligns with the broader goal of modernizing Bengaluru's urban infrastructure to meet the demands of rapid urbanization, increasing vehicular density, and the growing need for efficient intra-city mobility. By providing grade-separated corridors for vehicular movement, the project seeks to:

- Divert through-traffic from congested surface roads to elevated routes.
- Improve accessibility between major residential, commercial, and industrial zones.
- Reduce bottlenecks and travel delays during peak hours.
- Facilitate faster movement of goods and public transport.

- Support long-term urban and economic development through infrastructure enhancement.

The project is envisioned as a critical intervention in addressing Bengaluru's chronic traffic issues and will be integrated with other ongoing transport and infrastructure initiatives

1.3 SCOPE OF THE PROJECT

The scope of work includes:

i. Preparation of detailed project report (DPR) including detailed cost estimate.
ii. The Detailed Project Report (DPR) would include detailed alignment design, design of grade separated structures, design of service roads, pavement design, and quantities for civil construction items, cost for civil construction estimates as per Schedule of Rates and preparation of documents required for tendering.
iii. The Consultant shall follow relevant latest IRC publication and other circular on policy matters - Quality assurances manual. Layout and GADs are to be submitted for the structures including their approaches.
iv. Consultant shall prepare necessary technical document for submitting to all stake holders/department through B-SMILE for getting their inputs / approval.
v. Liaising with stake holders / department for identification of their utilities, assets and mapping of utility and assets falling in the project corridor.
vi. Conducting Detailed Topographical survey and preparation and submission of final Auto CADD format drawing
vii. Geotechnical investigation and submission of report.
viii. Traffic Survey.
ix. Liaising with Revenue Department officials for collection of revenue records required for land acquisition/TDR.
x. Preparation of Auto CADD drawing showing Existing Right of Way (EROW) / Proposed Right of Way (PROW)
xi. Preparation of Land Acquisition Plan and Schedule and Assisting B-SMILE for Preparation of Form-1 notification for TDR.
xii. Preparation of 3D model and Walkthrough of Proposed elevated corridors.

1.4 PROJECT CORRIDOR

The project proposal of elevated corridor from **West of Chord Road to Outer Ring Road (2.85 km):** Runs from West of Chord Road (Ch:0+000) through Mahalakshipuram, Ngapura, and Basaveshwaranagar to reach Outer Ring Road (Ch:2+850).

The Summary of length of the project corridor as per ToR is given below

Table 1.1: Details of Project Corridor

Sl No	Road Stretch	Length as Per ToR, Km	Length as Per Site in Km
1	"Preparation of Detailed Project Report (DPR) for Construction of Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout).	4.50	2.85
	Total Project Corridor Length, Km	4.50	2.85

A sketch indicating the alignment as per the contract agreement is shown below:

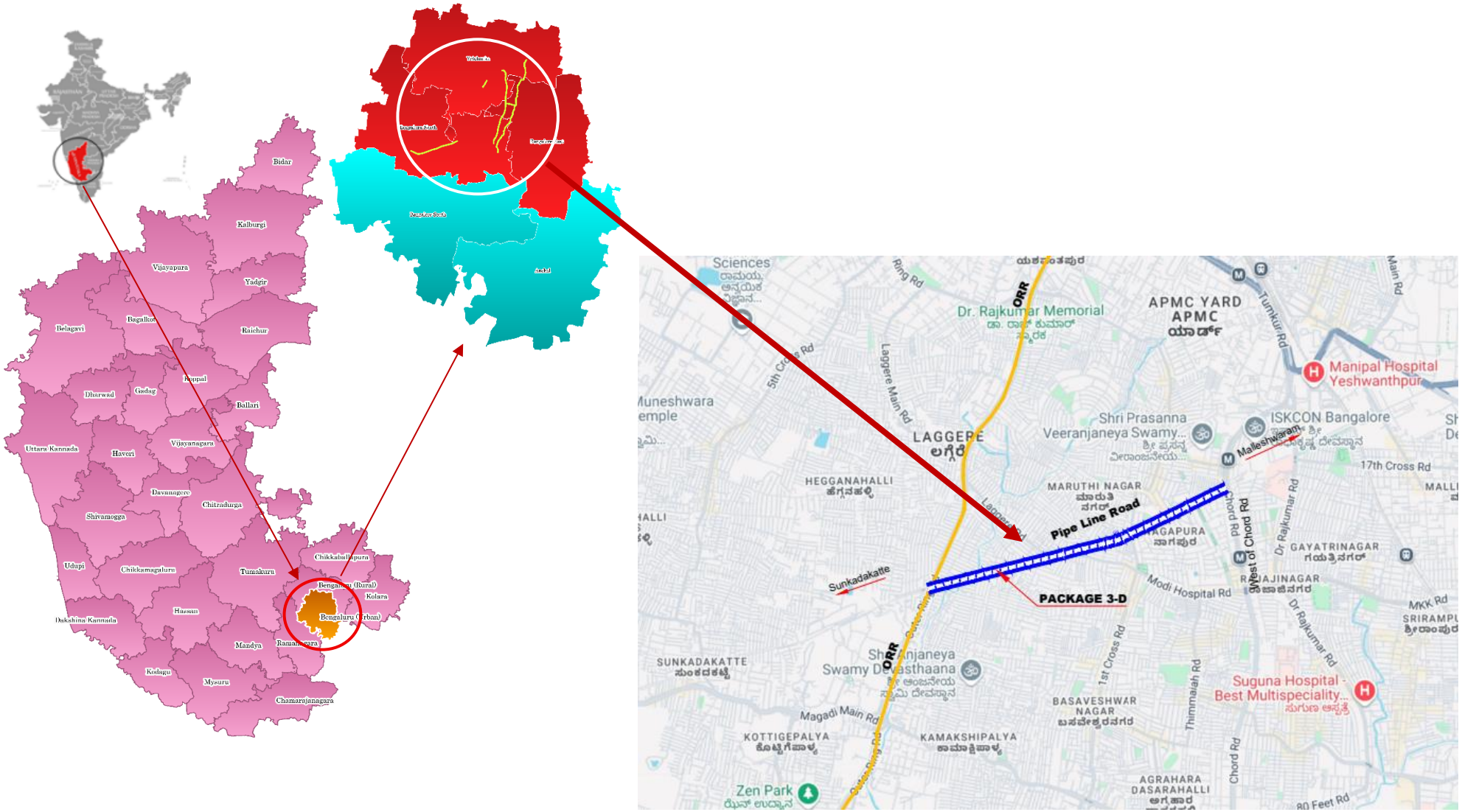

Figure 1.1 Location Map of Project

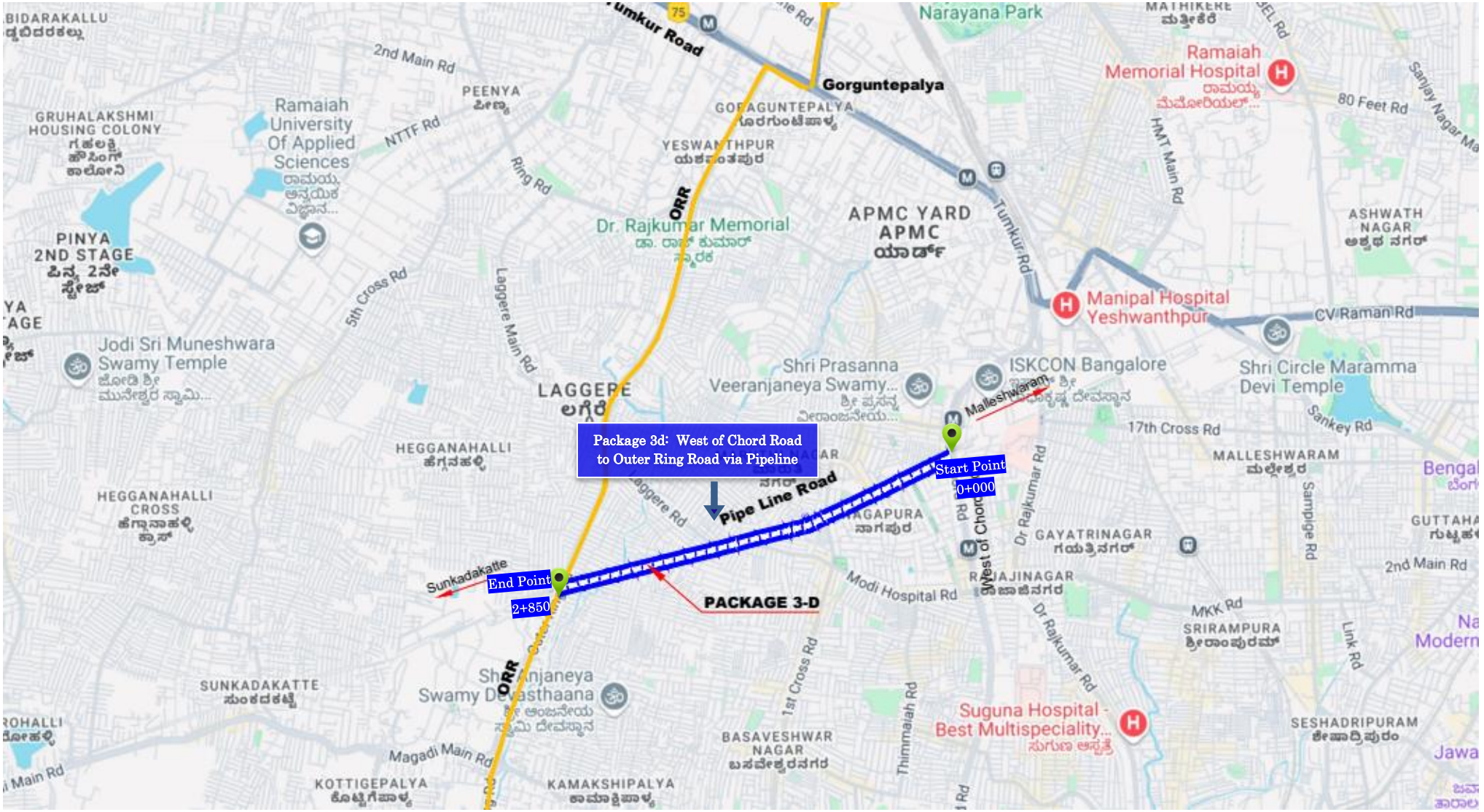

Figure 1.2 Key Plan showing the Alignment.

1.5 DESCRIPTION OF PROJECT ROAD

The project proposal comprises the preparation of a Detailed Project Report (DPR) for elevated corridor proposed to strengthen the road network, easing traffic congestion and improve mobility in the northern and eastern parts of Bengaluru. Together, these corridors aim to provide seamless connectivity between major arterial roads and peripheral growth areas, thereby reducing congestion on existing roadways.

The project proposal includes the Construction of Elevated Corridor from West of Chord Road to Outer Ring Road.

West of Chord Road - Outer Ring Road Corridor (2.20 km): This corridor is planned from West of Chord Road (Ch. 0+000) to Outer Ring Road (Ch. 2+850), passing through Mahalakshipuram, Nagapura, and Basaveshwaranagar. However, since a **flyover between Ch. 2+200 and Ch. 2+850 is already under construction**, the elevated corridor improvements will be limited to the section between **Ch. 0+000 and Ch. 2+200**. This intervention is expected to improve east–west connectivity and ease congestion along the adjoining internal road networks.

Accordingly, the Summary of Length of Proposed Elevated Corridor is given below

Sl No	Name	From	To	Length, m
1	Preparation of Detailed Project Report (DPR) for Construction of Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout)	0+000	2+200	2200
Total Improvement Length (Excluding Ramps & Loops), m				**2200**

1.6 STUDY METHODOLOGY

The methodology for carrying out the assignment is an important aspect. The Study methodology has been developed based on the project TOR requirements. The study has three stages, which are presented in **Figure 1.3**.

Stages of the Study

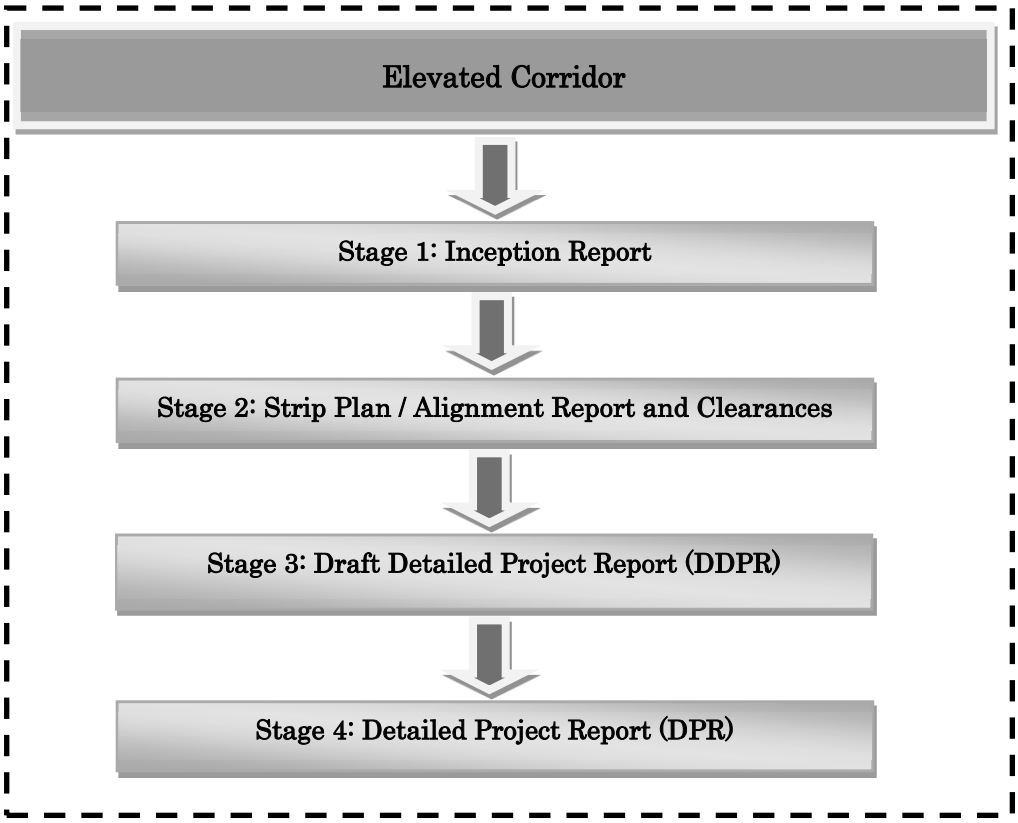

Figure 1.3 Stages of the Study

The following methodology is adopted for the completion of stages. The detailed proposed methodology was discussed and submitted in the inception report. However, an overview of the proposed methodology is as represented in flowchart and shown in Figure **1.4**.

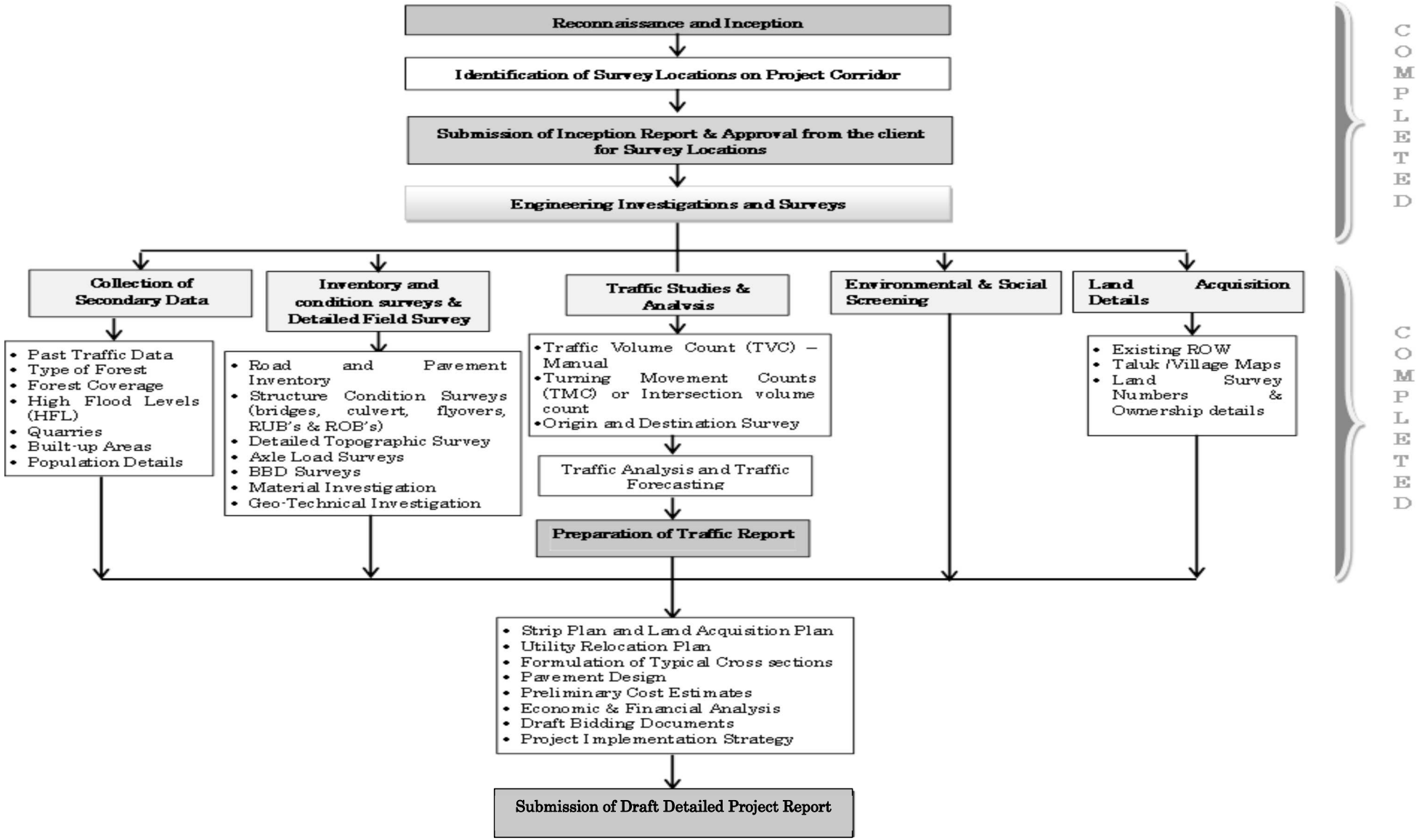

Figure 1.4 Proposed Methodology

1.7 DRAFT DETAILED PROJECT REPORT

The Draft Detailed Project Report will present the consolidated results of all surveys and investigations undertaken, along with preliminary designs, cost estimates, and related analyses in a conclusive manner. It will serve as a comprehensive reference document, forming the basis for subsequent stages of detailed engineering design and tender documentation. The Draft Detailed Project Report will also outline the proposed project implementation strategy, construction timelines, and tendering methodology under the procurement plan, including recommendations for suitable contract packaging.

As a part of Draft Detailed Project Report, the Consultant will conduct Preliminary Engineering Design of all aspects of the project as per relevant design code of practice as applicable in India and adopt international design standards if necessary. The preliminary engineering drawings will be prepared for all geometric, both horizontal and vertical of the elevated highway. It should be noted that proposals for drainage and utility shall be integrated with the existing facilities.

Accordingly, the Draft Detailed Project Report (Draft DPR) has been structured into following Four volumes:

- **Volume-I: Main Report,**
- **Volume-II: Design Report,**
- **Volume-III: Drawing Volume,**
- **Volume-IV: Cost Estimate.**

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CHAPTER 2. SURVEYS AND INVESTIGATIONS

2.1 GENERAL

This chapter presents the detailed surveys and investigations undertaken as per the Terms of Reference for the proposed **Elevated Corridor**. These surveys and investigations are crucial to guide the design, construction, and environmental management of both components of the project, ensuring that it meets the required technical, environmental, and social standards.

Following are the various engineering surveys and investigations other than traffic surveys were carried out. The Traffic Studies details are given in Chapter 4.

- Inventory and Condition Survey of Road;
- Pavement Condition Survey;
- Subgrade Investigations;
- CD Structure Inventory and Condition Survey;
- Detailed Topographical Surveys;
- LiDAR Survey;
- Material Investigation Surveys;
- Geo Technical Investigation Surveys;

2.2 INVENTORY, CONDITION SURVEY AND ANALYSIS

As per ToR, Road Inventory and Bridges / Flyover structures / CD structures inventory surveys have been conducted. Surveys are conducted as per the standard methodology / IRC guidelines. However brief methodology is given below:

As per the ToR consultants have to propose improvement proposals for the existing roads together with Elevated corridors along the project corridors. Hence, the road and bridge inventory and condition surveys were conducted accordingly.

The road inventory survey involves making visual estimates and actual measurements of geometric and cross-sectional elements of the road and its deficiencies. This survey involves the collection of the data pertaining to the existing road such as the width of the road, type of the shoulder and its width, type of terrain, longitudinal and vertical curves, number of CD structures, retaining walls, available land widths, nearby water bodies if any, number of trees, utility services etc. Road inventory has been recorded in a standard format.

The team has travelled and walked along the alignments and adjacent roads collected first-hand information on the width and type of carriage way, length between consecutive junctions, traffic intensity, width of footpath cum drain and relevant details of Grade separators, Metro Rail crossings and skywalks comprising in the proposed elevated corridor are noted.

2.2.1 Road Inventory

As per ToR, Road Inventory and Bridges / Flyover structures / CD structures inventory surveys have been conducted. Surveys are conducted as per the standard methodology / IRC guidelines. However brief methodology is given below:

As per the ToR consultants have to propose improvement proposals for the existing roads together with Elevated corridors along the project corridors. Hence, the road and bridge inventory and condition surveys were conducted accordingly.

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The salient physical features of the project corridor are as under:

Terrain:

The proposed project corridor traverses a predominantly urban built-up area within the Bengaluru Urban district. The alignment passes through relatively flat terrain with slight undulations in elevation, typical of metropolitan topography.

The terrain is characterized by dense development, limited right of way, high traffic volumes, and the presence of critical infrastructure such as railway lines, arterial

roads, commercial hubs, and institutional zones. Since the project lies within a major city, there are no natural valleys, hills, or bypasses like in rural alignments. Instead, the project navigates congested junctions and high-density corridors.

Land Use

The proposed alignment passes through a dense urban corridor with mixed land use, including high-density residential areas, commercial zones, major institutional establishments and recreational spaces

Carriageway and Shoulders

Measurements were taken at locations where the cross-section changes w.r.t Types and widths of Main Carriageway, Service Roads, Footpath, Median, and Drains from beginning to end of the project roads. Along with carriageway measurements and median as a part of inventory survey. The carriageway varies from Intermediate Lane to four lane divided carriageway. The Carriageway details for the Proposed Elevated Corridor are given in below Tables.

Table 2.1 : Details of Existing Carriageway (West of Chord Road to Outer Ring Road via Pipeline Road)

Design Chainage			Type of Pavement	Divided / Undivided	Main Carriageway width, m			Width of Shoulder, m		Width of Footpath, m		Width of Drainage, m				Width of Service Road, m	
From	To	Length, m			LHS	Median/Park	RHS	LHS	RHS	LHS	RHS	LHS		RHS		LHS	RHS
0+000	0+030	30	Flexible	Divided	8.8	16.5	11	-	-	-	-	1.4 + 2.1		1.5 + 1.9		-	-
0+030	0+110	80	Flexible	Divided	8.8	16.5	6.1	-	-	-	-	1.4 + 1.7		1.5 + 1.7		-	-
0+110	0+300	190	Flexible	Divided	8.8	16.5	5	-	-	-	-	1.4 + 1.7		1.5 + 1		-	-
0+300	0+430	130	Flexible	Divided	8.8	16.5	5.7	-	-	-	-	1.4 + 1.7		1.5 + 1.7		-	-
0+430	0+440	10	Flexible	Divided	8.8	16.5	8.5	-	-	-	-	1.4 + 1.7		1.5 + 2.3		-	-
0+440	0+560	120	Flexible	Divided	9	16.5	8.5	-	-	-	-	1.2 + 1.7		1.6 + 2.3		-	-
0+560	0+610	50	Flexible	Divided	9.5	16.5	8.5	-	-	-	-	1.8 + 1.7		1.8 + 2.3		-	-
0+610	0+620	10	Flexible	Divided	17.75	Median Opening	16.75	-	-	-	-	1.7		2.3		-	-
0+620	0+650	30	Flexible	Divided	9.3	16.5	8.5	-	-	-	-	1.2 + 1.7		1.5 + 2.3		-	-
0+650	0+950	300	Flexible	Divided	9.3	16.5	8.3	-	-	-	-	1.2 + 1.3		1.5 + 2.3		-	-
0+950	0+970	20	Flexible	Divided	16.8	Median Opening	15.8	-	-	-	-	1.2	1.3	1.5	2.3	-	-
0+970	0+990	20	Flexible	Divided	9.7	15	8.3	-	-	-	-	1.2	1.3	1.5	2.3	-	-
0+990	1+120	130	Flexible	Divided	9.7	15	5.5	-	0.5	-	-	1.2	-	1.5	1.5	-	-
1+120	1+240	120	Flexible	Divided	9.7	15	6.5	-	-	-	-	1.2	-	1.5	1.2	-	-
1+240	1+320	80	Flexible	Divided	10	15	6.5	-	0.5	-	-	1.4	-	1.5	1.2	-	-
1+320	1+410	90	Flexible	Divided	10	15	6.8	-	-	-	-	-	-	-	1.3	-	-

Design Chainage			Type of Pavement	Divided / Undivided	Main Carriageway width, m			Width of Shoulder, m		Width of Footpath, m		Width of Drainage, m				Width of Service Road, m	
From	To	Length, m			LHS	Median/Park	RHS	LHS	RHS	LHS	RHS	LHS		RHS		LHS	RHS
1+410	1+430	20	Flexible	Divided	16.35	Median Opening	13.15	-	-	-	-	-	-	-	1.3	-	-
1+430	1+680	250	Flexible	Divided	11.4	12.7	7.5	-	-	-	-	-	-	-	1.2	-	-
1+680	1+860	180	Flexible	Divided	11.4	12.7	7.2	-	-	-	-	-	1.5	-	1.5	-	-
1+860	1+930	70	Flexible	Divided	15.3	12.7	7.2	-	-	-	-	-	1.5	-	1.5	-	-
1+930	2+100	170	Flexible	Divided	15.3	12.7	7	-	-	-	-	-	1.7	-	1.7	-	-
2+100	2+120	20	Flexible	Divided	12.2	Median Opening	8.2	-	-	-	-	1.3	-	1.2	1.8	-	-
2+120	2+180	60	Flexible	Divided	5.1	17	7	-	-	-	-	-	1	1	1	-	-
2+180	2+190	10	Flexible	Divided	5.1	17	6.2	-	-	-	-	-	1	1	1	-	-
2+190	2+270	80	Flexible	Divided	5.6	17	6.2	-	-	-	-	1	1.4	1	1	-	-
2+270	2+320	50	Flexible	Divided	4.8	17	6.2	-	-	-	-	1.5	-	1	1	-	-
2+320	2+330	10	Flexible	Divided	4.8	17	6.2	-	-	-	-	1.5	-	1	1	-	-
2+330	2+470	140	Flexible	Divided	6.5	No access to road		-	-	-	-	1.7	1.2	-	-	-	-
2+470	2+580	110	Flexible	Divided	6	No access to road		3.1	-	-	-	2.3	-	-	-	-	-
2+580	2+720	140	No access to road					-	-	-	-	-	-	-	-	-	-
2+720	2+850	130	Flexible	Undivided	17			10	-	-	-	-	-	-	1	-	8
Total		**2850**															

Road Junctions

The proposed project alignment intersects several major road junctions along its route. These junctions are critical nodes in the city's traffic network, often experiencing high traffic volumes and congestion, particularly during peak hours. As part of the Detailed Project Report (DPR) preparation, key junctions along the corridor have been identified to improve traffic flow, ensure safety, and minimize conflicts between local and through traffic. The following is a list of major junctions along the proposed corridor.

Table 2.2 : List of Intersections along Project Corridor

Sl. No.	Design Chainage	Type of Junction	Category of Cross Road	Side	Remarks
1	0+000	T junction	Arterial Road	BHS	West of chord road
2	1+420	+ Junction	Collector street	BHS	Kurubrahalli circle
3	2+120	Staggered junction	Local Street	BHS	Kaveri Nagar Circle

Bus Bays and Bus Shelters

The Details of existing Bus Bay / Shelter / Stops are shown in the below tables which are available on the site:

Table 2.3 : List of Bus Bay / Shelter / Stops along Project Corridor

Sl No	Design Chainage	Location	Side	Remarks
1	0+000	Rajajinagar 1st Block	LHS	Bus Stop
2	0+620	Hotel Aditya	RHS	Bus Stop
3	0+970	Bheemajoythi Nagar Shankar Mutt	LHS	Bus Stop
4	1+470	Kuruburahalli	RHS	Bus Stop
5	1+550	Kuruburahalli	LHS	Bus Stop with Shelter
6	1+760	JC Nagar	LHS	Bus Stop
7	2+040	Cauvery Nagar	BHS	Bus Stop with Shelter

Right of way

The Existing Right of Way (RoW) along the project corridor has been established through field measurements taken at regular intervals, either from drain-to-drain or from the outer edge of the footpath, wherever applicable. The observed RoW details for Project Corridor are as follows:

Project Corridor - West of Chord Road to Outer Ring Road Corridor: RoW typically varies between 9.4 m and 45 m.

The Right of Way details along the project corridor is as mentioned below:

Table 2.4 : Right of Way along Project Corridor

Design Chainage			Right of Way (RoW), m
From	To	Length, m	
0+000	0+030	30	43.2
0+030	0+110	80	37.7
0+110	0+300	190	35.9
0+300	0+430	130	37.3
0+430	0+440	10	40.7
0+440	0+560	120	40.8
0+560	0+610	50	42.1
0+610	0+620	10	38.5
0+620	0+650	30	41
0+650	0+950	300	40.4
0+950	0+970	20	38.9
0+970	0+990	20	39.3
0+990	1+120	130	34.9
1+120	1+240	120	35.1
1+240	1+320	80	36.1
1+320	1+410	90	33.1

Design Chainage			Right of Way (RoW), m
From	To	Length, m	
1+410	1+430	20	30.8
1+430	1+680	250	32.8
1+680	1+860	180	34.3
1+860	1+930	70	38.2
1+930	2+100	170	38.4
2+100	2+120	20	24.7
2+120	2+180	60	32.1
2+180	2+190	10	31.3
2+190	2+270	80	33.2
2+270	2+320	50	31.5
2+320	2+330	10	31.5
2+330	2+470	140	9.4
2+470	2+580	110	11.4
2+580	2+720	140	0
2+720	2+850	130	38
Total		**2850**	**9.4 m to 45 m**

2.2.2 Pavement Condition Survey

The survey regarding road inventory and pavement condition was carried out along the project corridor. The width of the carriageway along the project road varies from Intermediate Lane to four lane divided carriageway. Visual inspection of the road showed a generally Fair surface condition.

The condition of the pavement has been evaluated based on the field measurements of primary pavement surface distress of cracking (narrow and wide), patching, raveling and potholes, noted for each kilometer length. The extent of each distress has been visually estimated for every kilometer length of the road in terms of percentage area affected and then averaged for one-kilometer road length.

The distress conditions are measured under the following sub-heads:

- Cracking (%)
- Potholes (%)
- Raveling (%)
- Patching (%)
- Settlement & Upheaval (%)

2.2.2.1 Cracks

Pavement cracking is a typical failure commonly observed in flexible / bituminous pavements occurring predominantly due to the higher number of repetitions of heavier axle loads. The pavement condition survey indicates that the average crack density for Project Corridor (West of Chord Road – ORR Corridor) is 5.00%.

2.2.2.2 Patching

No significant patching is noticed except at few localized spots. The pavement condition survey indicates that the average patching area for Project Corridor (West of Chord Road – ORR Corridor) is 1.00%.

2.2.2.3 Ravelling

Disintegration of the pavement surface caused due to failure of binder to hold the material together causing blowing off of fine aggregates leaving behind pock marks and when larger particles are broken free with stripping of aggregates is termed as Raveling. The pavement condition survey indicates that the average ravelling for Project Corridor (West of Chord Road – ORR Corridor) is 10.0%.

2.2.2.4 Potholes

Potholes are bowl-shaped holes of varying sizes in the surface layer extending into the base course. Potholes are mainly formed due of loose base course or base course not covered properly with wearing course or due to inadequate bonding between base course and subsequent top layers. The pavement condition survey indicates that the average pothole density for Project Corridor (West of Chord Road – ORR Corridor) is 1.20%.

2.2.2.5 Rutting

Rutting is a surface depression in the wheel path. Pavement uplift (shearing) may occur along the sides of the rut. Ruts are particularly evident after a rain when they are filled with water. There are two basic types of rutting: mix rutting and subgrade rutting. Mix rutting occurs when the subgrade does not rut yet the pavement surface exhibits wheel path depressions as a result of compaction/mix design problems. Subgrade rutting occurs when the subgrade exhibits wheel path depressions due to loading. In this case, the pavement settles into the subgrade ruts causing surface depressions in the wheel path. Pavement Rutting (%) along the project corridor is minimal.

2.2.2.6 Summary of Observations on Pavement Condition

The overall pavement condition along the project corridor is assessed to be in fair to good condition. For Project Corridor (West of Chord Road – ORR Corridor) 82.80%, indicating generally satisfactory surface performance with only minor distress requiring routine maintenance, the percentage various of destresses for each road is shown below.

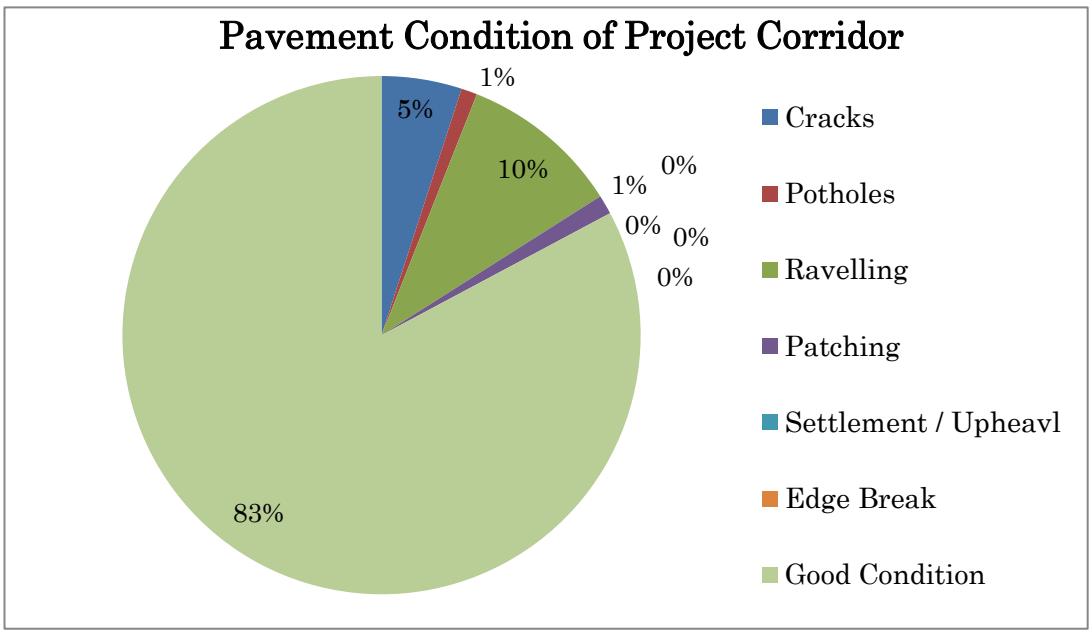


Figure 2.1:- Summary of existing Pavement condition for Project Corridor

2.2.3 Road Drainage

Roadside drain was observed either in lined or unlined type along the project road and the details are provided in annexure of this report.

Table 2.5 : Drain Details along Project Corridor

Design Chainage			Drainage					
From	To	Length, m	(Opened / Closed	Width		(Opened / Closed	Width	
0+000	0+030	30	C	1.4	2.1	C	1.5	1.9
0+030	0+110	80	C	1.4	1.7	C	1.5	1.7
0+110	0+300	190	C	1.4	1.7	C	1.5	1
0+300	0+430	130	C	1.4	1.7	C	1.5	1.7
0+430	0+440	10	C	1.4	1.7	C	1.5	2.3
0+440	0+560	120	C	1.2	1.7	C	1.6	2.3
0+560	0+610	50	C	1.8	1.7	C	1.8	2.3
0+610	0+620	10	C	-	1.7	C	-	2.3
0+620	0+650	30	C	1.2	1.7	C	1.5	2.3
0+650	0+950	300	C	1.2	1.3	C	1.5	2.3
0+950	0+970	20	C	1.2	1.3	C	1.5	2.3
0+970	0+990	20	C	1.2	1.3	C	1.5	2.3
0+990	1+120	130	C	1.2	-	C	1.5	1.5
1+120	1+240	120	C	1.2	-	C	1.5	1.2
1+240	1+320	80	C	1.4	-	C	1.5	1.2
1+320	1+410	90	-	-	-	C	-	1.3
1+410	1+430	20	-	-	-	C	-	1.3
1+430	1+680	250	-	-	-	C	-	1.2
1+680	1+860	180	C	-	1.5	-	C	1.5
1+860	1+930	70	C	-	1.5	-	C	1.5
1+930	2+100	170	C	-	1.7	-	C	1.7
2+100	2+120	20	C	1.3	-	C	1.2	1.8
2+120	2+180	60	C	-	1	C	1	1
2+180	2+190	10	C	-	1	O/C	1	1
2+190	2+270	80	C	1	1.4	O/C	1	1
2+270	2+320	50	C	1.5	-	O/C	1	1
2+320	2+330	10	C	1.5	-	O/C	1	1
2+330	2+470	140	C	1.7	1.2	-	-	-
2+470	2+580	110	C	2.3	-	-	-	-

Design Chainage			Drainage					
From	To	Length, m	(Opened / Closed	Width		(Opened / Closed	Width	
2+580	2+720	140	-	-	-	-	-	-
2+720	2+850	130	-	-	-	C	-	1
Total		2850						

2.2.4 Inventory of Existing Structures Details

The Inventory of all the structures (Bridges, Viaducts, ROB's/RUB and other grade separate structures, culverts, etc.) are carried out and all the details presented in a tabular form below.

Table 2.6 : Summary of Existing Structures

Sl No	Structure Type	No's
NIL		

2.2.5 Details of Existing Grade Separators & Cross Drainage Structures

The details of observed structures are presented below. In case any cross-drainage structures are encountered along the proposed alignment, efforts will be made to avoid them through suitable design adjustments, thereby minimizing reconstruction requirements and ensuring continuity of natural drainage:

Table 2.7 : Details of existing Grade Separators Project Corridor

Sl No	Design Chainage	Existing Span Arrangements in m	Type of Structure	Remarks
NIL				

Table 2.8 : Details of existing Bridges and Culverts Project Corridor

Sl No	Design Chainage	Type of Structure	Remarks
1	0+080	RCC Slab	Cross Drainage
2	0+560	RCC Slab	Cross Drainage
3	1+340	RCC Slab	Cross Drainage
4	2+330	RCC Slab	Cross Drainage
5	2+340	RCC Slab	SWD Drain
6	2+470	RCC Slab	(SWD Drain Crosses)
7	2+850	Box Structure	Underpass

2.2.6 Utility Survey

A comprehensive utility survey is a critical component of urban infrastructure projects, ensuring effective project planning, coordinated execution, and minimizing disruption to existing utility services during construction. For the project Elevated Corridor, detailed utility information was obtained through formal correspondence with relevant utility agencies, including the Bangalore Water Supply and Sewerage Board (BWSSB), BESCOM, Karnataka Urban Water Supply & Drainage Board (KUWSDB), Minor Irrigation Department, GAIL Gas Limited, Optical Fibre Cable (OFC) service providers, and BMRCL Utility departments.

Following the receipt of utility data from these agencies, at required locations field surveys were conducted with corresponding officials to verify and supplement the collected information. During the field inventory and from the departments, all utilities including water pipelines, sewer lines, electrical infrastructure, gas pipelines, OFC routes, and other telecommunication services were recorded/collected. This process enabled a comprehensive mapping of utilities along the alignment and facilitated identification of potential conflicts with the proposed elevated corridor. In densely built urban contexts like Bengaluru, such utilities are often located within restricted right-of-way or adjacent to existing road infrastructure. Proper identification and planning are therefore essential to avoid service interruptions, ensure safety, and optimize construction sequencing, particularly for elevated structures spanning multiple intersections and arterial roads.

All details of utility lines should be captured in survey. Details of utilities to be shifted or re-laid shall be identified and the same shall be marked on the Drawings to enable submission to the respective utility providers for further actions. All coordination and assistance required in this aspect shall be provided by the consultant

The details of utilities identified within Package 03 are given in the annexure. Notably, Low Tension (LT) & High Tension (HT) electrical lines/poles, water & sewage networks, Gas Pipelines and Optical Fibre Cable (OFC) routes are present along the corridor, necessitating careful coordination during construction to avoid service disruption, enable relocation where required, and maintain continuity of critical urban services.

All the important physical features along the alignment are collected and are shown in the below tables:

Table 2.9 : Details of Existing Utilities along Proposed Elevated Corridor

Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout).							
SL. No	Chainage Design		Utility Type (Water/Sewer/Storm Water/etc.)	Utility Type (HT/LT/Transformer etc.)	Utility Type (Canal/Drain Irrigation pipe etc.)	GAS Pipeline	OFC Cable
	From	To					
1	0+000	0+300		@ 10 electric box RHS Park side @ 5 Electric box RHS P - side @ 11 Kv cable croassing @ parallel Road @ 310 T.P A pole RHS (park side)			
2	0+300	0+560		T.P Pole A Box @ RHS park side @ C.W Edge @ 350 CH	@ 290 LHS Park side Borewell @C.W edge @530 LHS (park side) water pipeline @ C.W Edge 1m		
3	0+560	0+620		1 KV Bescom @ parallel service road @Ch: 30 LHS transform Junctioin Box @ C.W Edge 1m 11KV Bescom RHS @ park side position @ C.W edge @Ch: 40 - LHS park side Transformer on C.W Edge @1m			On LHS @ C.W edge
4	0+620	0+900	UGD @ RHS P-side @ 1.5m C.W edge	T.P pole A box @ RHS park side 1m C.W Edge T.P pole A box @ RHS park side @ F/D @ 570			
5	0+900	0+970	UGD @ LHS center of road UGD @ LHS @ Property side 1m from C.W Edge	@ 815 LHS (park side) transformer @ C.W Edge			@820 LHS Property side C.W edge 0.6 x 1.2 OFC Chamber
6	0+970	1+430	UGD @ RHS Park side @ C.W edge @ 2m				
7	1+430	1+860	UGD @ LHS Property side UGD @ LHS Property side @1.5 m C.W Edge	11KV @ LHS (property side) @ C.W edge @2.5m @ C.W Edge @1m Park side			@ 1230 LHS Property side OFC chambers - 3 no's @ C.W Edge @ 1.5m @ 1430 OFC chamber park side @ C.W Edge
8	1+860	1+930	UGD @ Park side - RHS -@ C.w Edge 1m watet purest chamber @ RHS - p-side @ c.W 1m @ 1425	Transformer @ RHS Park side @ F/D @ 1220 T.P @ RHS (park side) @ 1820 @F/D At 1680 RHS @ p-side @ F/D Transformer At 1450- (park side) - RHS T.P @ C.W Edge @ 1.5m	At 1+800 RHS @ park side Borewell @ C.W Edge @ 1m At 1540 RHS @ park side Borewell @ C.W Edge @1m		Att 1+790 RHS park side T.P Box A OFC chamber @ C.W Edge A F/D OFC Chamber @ 1570 RHS @ p-side @ C.W edge - 1m OFC Chamber @ 1530 - RHS - P-side @ C.W Edge @ 1m OFC Chamber - 2 No's RHS - p-side - C.W Edge @ 1.0m

Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout).							
SL. No	Chainage Design		Utility Type (Water/Sewer/Storm Water/etc.)	Utility Type (HT/LT/Transformer etc.)	Utility Type (Canal/Drain Irrigation pipe etc.)	GAS Pipeline	OFC Cable
	From	To					
							OFC -chamber- 1420 @ P-side @ C.W edge 1m
9	1+930	2+100	LHS UG @ P-side @1 -2m Edge				
10	2+100	2+180	UGD @ RHS (p-side) @ C.W Edge @ 1m				OFC Chamber @RHS @ Park side @ C.W Edge @ 1.5m
11	2+180	2+270		Transformwet ch; 2200 LHS @ property side @ C.W Edge 1m			
12	2+270	2+320	UGD @ RHS (properety side) @ C.W Edge @ 1m				
13	2+320	2+470					
14	2+470	2+580	LHS UGD @ Park side @ 1m C.W Edge LHS UGD @ 2340 - property side @2580 1m C.W Edge UGD @ Center of Road		@ 2340 LHS SWD Cross		@ 2470 to 2580 OFC line at park side @ R/P 2480 - OFC - Chamber @ C.W Edge SWD Drain side

2.3 TOPOGRAPHICAL SURVEYS

As per ToR, topographic survey has to be conducted along the project stretches. The main purpose of the topographical survey was to produce digital 3d base maps showing the existing terrain including all existing road features including houses, telephone line, OFC, electric line, monuments, place of worship, cremation ground, utility line, trees, hand pumps and other features covering the entire right of way of the road. The digital 3d base maps are the basis for preparation of the digital terrain models (dtm) required for the road design.

The methodology as per terms of reference (ToR) was adopted for topographical survey by the consultants for capturing all the physical features along the project corridor for facilitating proposals for the final center line of the proposed 2/4-lane road, keeping in view the possible local realignments. The corridor for survey is at least 30 m beyond either side of the center line of the proposed divided carriageway or land boundary and additional width for interchanges and intersections. This survey includes reading spot levels along L-section at every 25m interval, cross sections at every 50m interval, fixing GPS/ Benchmarks at every 5 Km interval and the Reference Benchmark Pillars at every 250m interval connected to GTS Benchmarks as specified in TOR.

The project road alignment was surveyed and Reference / Bench Mark pillars for horizontal and vertical control were fixed on the ground along the project road as per TOR. The scope of Consultancy was to carry out the topographic survey to cover following aspects:

- Control Surveys
- GPS Control
- Total Station Traverse
- Height Control

2.3.1 Control Surveys

The control traverse is the base framework for all the further survey work. This provides a coordinated horizontal grid and a level reference system to ensure accuracy. Thus, the measured coordinates of these survey grids (Northing and Easting) and the levels are tied to GTS benchmark wherever available, to verify the accuracy of survey.

The control survey is carried out in two phase survey. Horizontal control using GPS and Total Station. Vertical control using auto level Control points (cement concrete pillars) established at an interval of about 2-km along the road, using differential GPS techniques. Twin pillars were fixed at these locations so as to enable further control (200 to 300 m apart) along the road using total station traverse. The location of these GPS pillars fixed at site in such a way that GPS observation to the satellite can be carried out without any obstruction and these cement concrete pillars are available as permanent benchmarks for survey and layout at later stage.

All the GPS control pillars are uniquely numbered and described so that these can be easily located and accessed for future work.

The anticipated accuracy of the above control points will be:

- Planimetric accuracy of GPS control points: 10 mm + 5 ppm
- Adjustment accuracy of secondary traverse control points fixed by total station: better than 1:10,000

For elevations using auto-levels, the agreement with the reference benchmarks will be better than $12\sqrt{K}$ mm, K stands for distance surveyed between the benchmarks in kilometers.

2.3.2 GPS Control Survey (Primary Control)

GPS survey is the primary control survey in topographical survey. The sequence activities involved in this survey are:

- Established GPS control pillars at every 5 km along the project corridor
- Collected GPS signals at an arbitrary station for a period of about 2 (two) hours so as to compute the geographic coordinates of this point to an accuracy of few decimeters.
- Taking the above as the known point, determine the relative geographic coordinates of all geodetic and azimuth controls to an accuracy of 1: 50,000 or better from its nearest geodetic control
- Project the geographic coordinates onto a suitable grid

Three sets of receivers (make Leica GS20 with Leica AT501 external antenna) mounted on conventional aluminum tripod and centering device (tribrach + carrier) were used for data acquisition. GPS data were downloaded from the receivers, post processed, verified

for loop closure and networks adjusted at select locations. The geographic coordinates of all control points were determined on WGS84 datum.

However, as the control points are being established to correct ground (ETS) survey observations, the geographic coordinates of the control points were projected on two alternative local grids.

The location of GPS pillars was marked on base map drawing and northing and easting values also shown at every control point. A List of GPS Pillar location along the project Road is appended to this report.

2.3.3 Total Station Traverse (Secondary Control):

Total station traverse in between GPS control points is basically to distribute the control points along project road to facilitate further use of them to read all topographical features. After successful completion of primary control points, secondary control points were established with total station. An open traverse was run along the existing road beginning from known GPS point and closed on the next GPS control pillar. The amount of error found after closing the traverse on successive GPS point is distributed equally on all stations, which are established during traversing in between those GPS points. If the amount of error is more than the permissible limits, the whole process was repeated until the results are satisfactory. Foresight and back sight distances of traverse station maintained equally to minimize the angular error.

2.3.4 Height control and Bench marks pillars:

The elevation of all the control points fixed by GPS and total station are established using auto levels, connecting to GTS bench marks procured from Survey of India. Precision levelling has been carried out by two levelling teams in fore and back direction and mean will be taken to establish the elevation of all cement concrete pillars, and other control points, using auto-levels. This established control work of plan and height would enable topographical survey on systematic accurate and scientific basis.

Bench mark/ reference pillar of size 15cm x 15cm x 45cm casted in RCC of M15 grade with a nail fixed in the center of the top surface. These pillars are embedded in concrete up to a depth of 30cm with CC M10 (5 cm wide all around). The balance 15cm above ground has been painted and BM numbers are given to each pillar. These numbers along with RL value are shown in base map. The interval of these bench marks pillars are 250m along

the project road as per TOR. A List of bench marks location along the project Road is appended to this report.

2.3.5 Feature Codes:

The feature code is an alphanumeric code assigned to each topographical feature to represent and communicate between surveyor and highway design engineer. Before picking of any feature the surveyor will assign the feature code to that particular feature and collect the x, y, z of that feature. Coding for feature shall comprise of four characters, first two characters describing the feature and last two characters mentioning the string number. All the surveyed points with same string name shall be joined, (eg. Road centerline, shoulder, building, etc.). All the features that are not joined (eg. Telephone poles, trees, spot levels, etc.) Shall have their codes start with P. No feature shall have its survey code starting with M, L or G. A predefined list of feature codes has been prepared and handed to surveyors. An initial training to field surveyors has been given by highway engineer to get acquaintance of these codes. A list codes used to this project are appended to this report.

2.4 LiDAR Survey

LiDAR (Light Detection and Ranging) technology was adopted for the topographic survey of the project corridor to achieve highly accurate and detailed mapping of existing ground features. The survey was carried out using a combination of mobile LiDAR mounted on survey vehicles and GNSS-based positioning systems to collect georeferenced three-dimensional point cloud data along the entire alignment.

The system uses laser pulses emitted at a very high frequency, which, upon striking the surface, return to the sensor to calculate precise distances. This results in a dense point cloud with millions of data points, capturing the exact location and elevation of the road surface, adjacent shoulders, medians, structures, utilities, roadside features, and natural terrain. The LiDAR data was processed to remove noise and classify points into categories such as ground, vegetation, and man-made structures. From this classified data, highly accurate Digital Terrain Models (DTM) and Digital Surface Models (DSM) were generated.

The LiDAR survey methodology significantly reduces field survey time compared to traditional total station or DGPS surveys while delivering sub-decimeter accuracy. It

enables detailed corridor mapping even in areas with heavy traffic, dense built-up zones, or inaccessible locations, without the need for prolonged traffic disruption.

For this project, LiDAR surveying has been employed along the entire proposed alignment, covering all the elevated corridors. The high-resolution point cloud data generated has been utilised for preparing the base maps, alignment design, longitudinal and cross-sections, and for identifying and mapping existing utilities and structures. This ensures that the DPR is based on precise, up-to-date spatial information, thereby enhancing the accuracy of design and minimising potential construction conflicts.

2.5 GEOTECHNICAL INVESTIGATIONS AND SUB-SOIL EXPLORATIONS

2.5.1 Geo-Technical Investigations

The investigation programme is for carrying out of boreholes at specified locations, up to a competent stratum as per IRC and BIS, recovering undisturbed and disturbed samples from the borehole, and carrying out the required in-situ tests on the soil in the borehole. The soil samples recovered have been properly packed, sealed, labeled and taken for testing of various soil properties, including

index properties, grain-size distribution, shear and consolidation parameters, and other related tests. The depth of borehole has been fixed depending on the type of structure, type of soil or nature of stratum, taking into account the provisions of IRC-78: 2014. The Geo-technical Engineer has supervised the boring, sampling and testing operations. The agency carrying out the sub soil exploration was monitored in using the right equipment, in good condition, to recover the soil samples, using thin-walled samplers. Where rock is met with, proper core barrels have been used for recovery of rock cores. In cases of soft soils, undisturbed samples are recovered in thin-walled sampling tubes, to avoid sampling disturbance. The samples were sealed to preserve the natural moisture content and tests on shear strength and compressibility have been conducted. The soil a stratum was recorded during drilling on bore logs, as per the pro-forma given in IRC: 78-2014.

During the operations, proper drilling tools and drilling and sample recovery procedures have been adopted and monitored. Preserving of samples by sealing and waxing has been carried out. All tests have been conducted as per IRC and IS codes of practice. Some of the relevant codes which were used for investigation and testing are IS: 192 - Code of Practice for Site Investigations, IS: 1498 - Classification and Identification of Soils for General Engineering Purposes, IS: 2720

- Methods of Tests for Soils and IRC: 78, Section VII - Standard Specifications and Code of Practice for Road Bridges, Foundation and Substructure.

Borehole surveys shall be conducted at approximately every 1 km interval along the entire length of the Proposed Elevated Corridors.

The report covers the details of boreholes drilled, sub-soil profile noticed and preliminary foundation recommendations. Details of Methodology of field investigation, Laboratory tests conducted on representative soil / rock samples collected from the boreholes, Sub soil profile analysis and interpretation of the same for Safe Bearing Capacity (SBC) and Foundation recommendations will be presented in Detailed Project Report.

2.5.2 Scope of Work

Brief scope of work includes of the following:

Drilling of boreholes of 150 /76 mm diameter in all types of soil/rock by using Rotary Drilling rigs Performing Standard Penetration Test (SPT) in the boreholes at every 1.5 m intervals till refusal

- Collection of UDS Samples in cohesive / semi-cohesive soils at 3.0 m intervals alternatively with SPT, if possible.
- Recording of water table level in the boreholes after completion of boring.
- Collecting Rock core samples from boreholes and record the Rock Quality
- Designation (RQD) and Core Recovery (CR).
- Conducting laboratory tests on relevant Soil /Rock samples as per IS Code specifications.
- Preparation and Submission of Geotechnical Investigation report summarizing the details of soil / rock classifications, analysis of test data and recommending the type of foundations to be adopted for the proposed Elevated Corridor.

2.5.3 Location Details of Corridor

The report covers the details of boreholes drilled, sub-soil profile noticed and interpretation of the same for Safe Bearing Capacity (SBC) and Foundation recommendations will be presented. Borehole surveys shall be conducted at approximately every 1 km interval along the entire length of the Proposed Elevated Corridors.

For the proposed Package 03, Borehole investigations are under progress and will be carried out as part of subsequent project submissions. The results of these additional surveys will be presented in further submissions.

2.5.4 General Sub Soil Profile and Recommendation:

The length of piles considering strata at pile termination at various borehole locations where hard strata is met at considerable depths for safe axial load of 360 to 400 tones is furnished below Table.

Table 2.10 : Socketing for Pile Foundations

Stratum at socket level	Depth of socketing (D = Pile diameter)
Hard Rock	1 to 2D
Moderately weathered Rock	2 to 3D
Soft Rock	3 to 4D

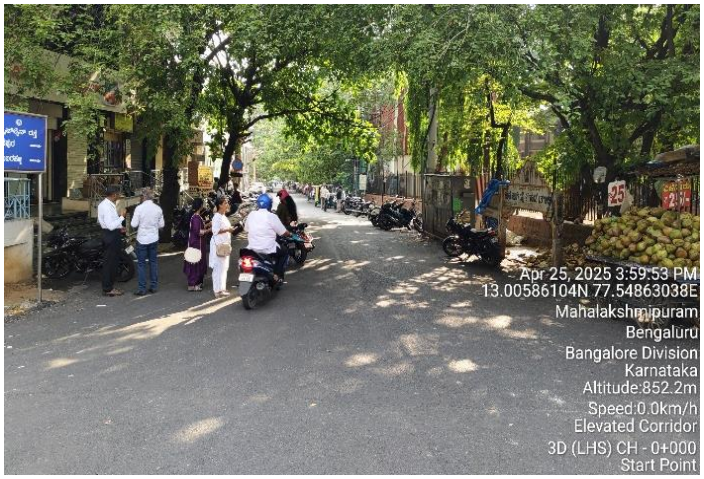
2.6 LAND ACQUISITION SURVEYS

The Common problem encountered in land acquisition includes non-availability of updated cadastral survey map from one source. Data has to be collected from various offices and the same has to be reconciled.

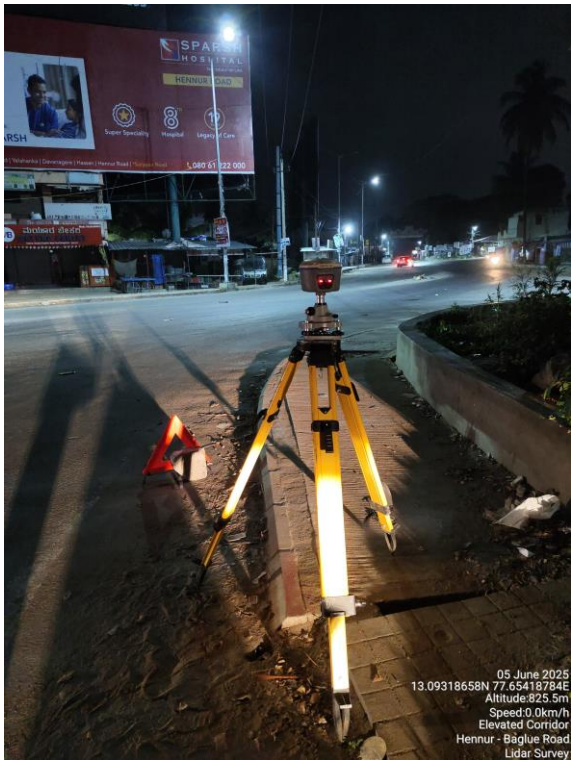
Land acquisition plan with area statement shall be prepared and enclosed with Drawing Volume During the Submission of Detailed Project Report.

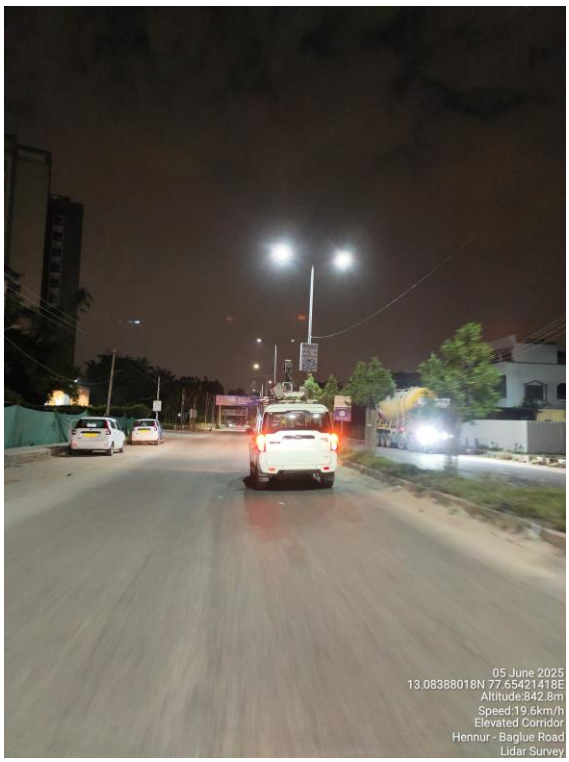
SITE PHOTOS

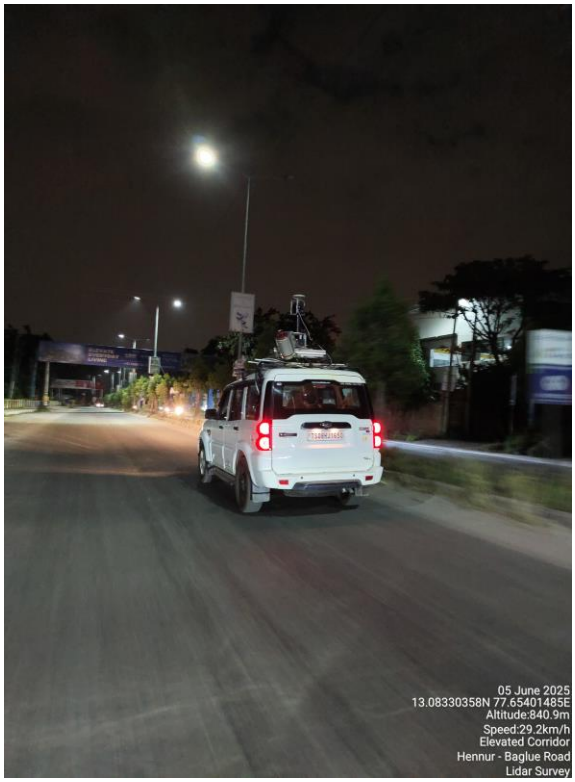
Existing Carriageway Photos

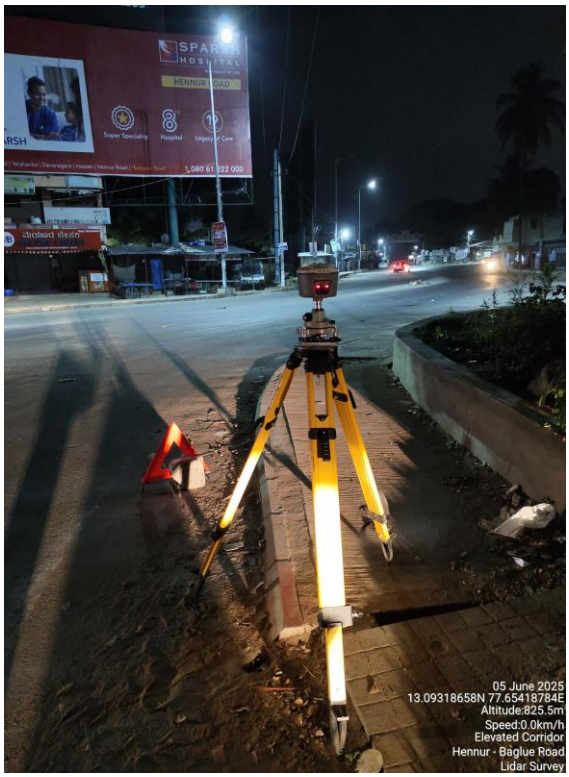


LiDAR Survey Photos









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CHAPTER 3. DESIGN STANDARDS AND SPECIFICATIONS

3.1 INDICATIVE DESIGN STANDARDS FOR DIVIDED CARRIAGEWAY

The aim is to provide maximum safety to the road users, in defining the highway geometry, carriageway, shoulder widths, embankments and other pertinent components for an uninterrupted and smooth flow of traffic. The approach adopted in achieving the safety is as follows:

- Provide appropriate cross traffic facilities without impeding traffic flow;
- Minimize impact on settlements and environment;
- Provide cost-efficient, but readily constructible facility with least hindrances, viz rehabilitation.

3.1.1 Reference Standards

IRC Standards will be used in general. However, where IRC does not cover any particular feature or aspect appropriately, AASHTO and other International Standards will be used for providing additional safety, namely, length of vertical curves in view of likely modernization of goods trucks in India (height of driver's eye), super elevation and radii of curve beyond which no super elevation is needed and extra widening on horizontal curves for smaller radii. AASHTO Standards for transition curves will be considered as appropriate.

3.2 DESIGN STANDARDS

3.2.1 Highway Design Standards

Geometric design of the elevated road and existing road at ground level shall be as per IRC: 86, IRC: 92, IRC: 65 and IRC: SP: 90 as well as other related codes taking into account the urban conditions. Uniformity of design standards will be maintained for the project corridor. Deficiencies in the existing geometry will be rectified to meet the minimum standards.

3.2.1.1 Design Speed

As far as possible, the design speed shall be 80/60 kmph and minimum speed shall be 50/30 kmph for elevated corridor. However, ramps and loop ramps shall be for 30 kmph. Unless otherwise there is site constrain from social and environmental point of view, generally the design speeds shall be maintained.

3.2.1.2 Road Land Width

As per the IRC 86, a minimum Right of Way of 45m for Arterial roads and 30m for sub-Arterial roads should be available. However, most of the Bengaluru urban roads do not have recommended right of way. On the other side, the traffic is growing exponential on these roads. Hence, to have smooth flow of traffic, within available RoW or with minimum land acquisition elevated corridors are proposed. As far as possible will try to accommodate the elevated corridor within the available land corresponds to each corridor. At few locations like short length narrow sections, curves, ramp / interchange locations, considering social/environmental aspects additional land requirement would be proposed. The client would acquire the additional land wherever required. The land to be acquired shall be indicated separately for each corridor after the finalization of alignment report, cross section and junction design.

3.2.1.3 Roadway Width

The standard lane width of the Project corridors shall be 3.5 m, the shyness shall be 500 mm for elevated corridor. For at grade road, due to construction of piers for elevated structure width of existing road will be reduced. Since land is a constraint and in urban conditions speeds will be less, hence lane width of 3.0 m and shyness of 250 mm is followed. This is in reference to the newly improved roads by BBMP under "Tender Sure" and other schemes, where the lane width is been standardized to 3.0 m. Overall roadway width for different cross sections are worked out separately and presented at the end of this chapter.

3.2.1.4 Shoulder Width

Width of Paved Shoulder on the outer side (left side of respective carriageway) shall be 1.5m along the entire length of the elevated corridor.

In accordance with IRC guidelines, the provision of a 1.5 m wide paved shoulder on the outer side of each carriageway along the elevated corridor not only enhances safety and operational efficiency but also contributes to an increase in traffic carrying capacity. Paved shoulders facilitate the lateral clearance of slow-moving or stationary vehicles, improve lane discipline, and provide additional recovery space for vehicles in case of emergencies. As per IRC:64–1990, such shoulders can improve the effective capacity of a corridor by approximately 15% compared to a similar facility without paved shoulders.

This design provision will therefore support smoother traffic flow, reduce travel time, and enhance the overall service level of the elevated corridor.

3.2.1.5 Median:

As per IRC SP 84:2019, width of median in urban areas is 2.5m including shyness. However, due to land constraints it is proposed to have 0.61m median (New Jersey Crash barrier) on proposed elevated corridors. At grade road median width will be guided by the width of pier of elevated structure. Mostly the width of pier including Protection wall is 3.0m. At portal frame proposed locations as far as possible existing median width will be maintained.

3.2.1.6 Sight Distance and Radius

For the proposed elevated corridor, the vertical alignment has been designed to comply with the minimum Stopping Sight Distance (SSD) requirements specified in the IRC 86. This ensures that, at all sections of the corridor, the available sight distance is equal to or greater than the minimum SSD necessary for a vehicle to come to a safe stop under design conditions. In locations where geometric constraints arise due to limited right of way or adjacent developments, the alignment has been optimised to achieve compliance while balancing safety, functionality, and constructability within the prevailing land constraints. The design values of sight distance are given in below

Sl No	Speed (km/h)	Safe Stopping Sight Distance (m)
1	20	20
2	30	30
3	40	45
4	50	60
5	60	80
6	70	105
7	80	120

As per IRC-92 Speed, Horizontal Curvature and Sight Distance for Ramp

Particulars	Design Values for Major Highway Design Speed of				For Loop Ramps	
	80 km/hr		100 km/hr		Minimum	Desirable
	Minimum	Desirable	Minimum	Desirable		
Ramp Design Speed (km/hr.)	40	50	50	65	30	40
Radius of Curvature (m)	60	90	90	155	30	60
Stopping sign distance (m)	45	60	60	90	25	45

The radius of horizontal curves shall not be less than the desirable minimum values given in above table except for sections where site constraints are available. At those locations lesser radius will be provided.

3.2.1.7 Gradients

The ruling and limiting gradients are given in below table. Ruling gradients shall be adopted as far as possible. Limiting Gradient shall be adopted in difficult situations and for short lengths.

Nature of Terrain	Ruling Gradient	Limiting Gradient
Plain and Rolling	2.5%	3.3%

At sections where there is acute land problem in case of providing the entry & exit ramps from the elevated structure then the limiting gradient has to be increased (Provided exceptionally up to 5% in constrained urban conditions for Arterial Roads).

IRC 92 & IRC: SP:90 mentions gradients in the range of 4 - 6%;

Depending upon the site constraints, the gradients in the range of 4 - 6% are used. Due to land constraints at few locations' ramps length have to be reduced, hence steeper gradients provided (i.e., in exceptional urban cases, 7% for short lengths - as per IRC: SP:90-2023).

3.2.1.8 Intersections

As part of consultancy agreement consultant need to improve at grade existing facilities. At grade intersections adversely influence the quality of roads in terms of speed, capacity and safety because of interruptions to the flow of traffic. Thus, the basic requirements for the design of intersections are not only to cater for safe movements for the drivers,

but also to provide them full traffic information by way of signs, pavement markings and traffic signals. Intersections will be designed in line with IRC SP 41 but limiting improvements within available RoW

3.2.1.9 Utility Corridor

As a part of at-grade road improvement proposal, utility corridors will be proposed at ground level on either side along the proposed elevated corridors route. As far as possible 2 m wide strip of land at the extreme edge of ROW shall be kept for accommodating utilities, both over as well as underground. However, no land will be proposed for acquisition. Provisions contained in IRC: 98 shall be followed as the project corridors fall in built up area. Utility Ducts in the form of 600mm diameter NP-4 Pipe across the Project corridor at a spacing of 500m shall be provided for crossing of Underground utilities. The provision of Utility corridor will be subjected to Land availability.

3.2.1.10 Traffic Control Devices and Safety Measures

Traffic Control Devices, Road safety devices and Roadside furniture shall comprise of road signs, road markings, object markers, hazard markers, studs, delineators, attenuators, safety barriers, pedestrian guardrails, boundary stones, km stones etc. Guidelines given in IRC: 25, IRC: 26, IRC: 35, IRC: 67, IRC: 79, IRC: 103 and section 800 of MORTH Specifications shall be used for providing these items unless otherwise specified.

3.2.1.11 Bus-Stops

The Bus stops (at ground level) will be redesigned, wherever the bus stops are disturbed due to construction of elevated corridor or if the existing roads are being widened. The bus stop structure shall be structurally safe, aesthetically pleasing and functional so as to protect the waiting passengers from sun, rain and wind. Adequate drainage arrangement shall be provided at bus stops and bus bays. Standard bus shelter plans that are being developed by BBMP is recommended.

3.2.1.12 Lighting System

Since the project corridors are traversing though the urban area Lighting shall be provided on elevated structure and lighting shall also be provided in soffit of the deck of elevated structure so that required illumination is available for existing ground level traffic. IS: 1944 (Part I and II) 1970 shall be followed in regard to lighting installations and also IRC: SP: 90 shall be followed.

3.2.1.13 Noise Pollution Barriers

Noise barriers are used as an effective measure of noise abatement. Different types of "green" noise barriers adapted to the surrounding environment are used. Size and conspicuousness of noise barriers and noise embankments leaves their mark on the environment. An increasing proportion of people's time is spent commuting on highways, and it is therefore an important task to make this time a positive experience through attractive surroundings. Noise screening can constitute an actual physical barrier in a town or housing area.

3.2.1.14 Pedestrian Facilities

The proposed elevated corridors are meant for only motorized vehicles. Hence, pedestrian facilities shall be retained/provided at ground level. Pedestrians are vulnerable to being involved in accidents. Therefore, adequate consideration shall be given to their safety through provision of facilities.

3.2.1.15 Footpaths (sidewalks)

The width of sidewalks depends upon the expected pedestrian flow and shall be fixed subject to land availability, but shall not be less than 1.5m wherever land available.

3.2.1.16 Pedestrian crossings

Facility for crossing the carriageway by the pedestrians shall be provided through pedestrian underpass. At-grade pedestrian crossings shall be controlled. Controlled form of crossing shall be achieved through provision of Zebra Crossings, whether at signalized intersection or pedestrian actuated signal.

3.3 Geometric design

3.3.1 Introduction

Geometric design for the project corridors has been undertaken in accordance with the design standards presented in the *Inception Report* and further detailed under *Summary of Proposed Cross-section* (Table: Geometric Design Standards for Project Corridors). At certain locations, due to prevailing site constraints, the design has been adapted to accommodate reduced design speeds. In such cases, appropriate safety measures such as provision of regulatory and warning signs, pavement markings, and other traffic calming features have been incorporated to alert and guide drivers.

The alignment and route planning of the project corridors have been discussed in detail, with geometric refinements made based on updated topographic survey data, physical site constraints, and the objective of minimizing land acquisition. Corridor-wise geometric details are presented in the following sections.

3.3.2 West of Chord Road - Outer Ring Road Corridor via Pipe line Road

The proposed elevated corridor extends from **West of Chord Road (Ch. 0+000)** and terminates before the Outer Ring Road at **Ch. 2+200** along **Pipeline Road**, covering a total length of **2.20 km**. From Ch: 2+200 to Ch:2+850 a Grade Separator is under construction. The alignment passes through key traffic junctions such as **Mahalakshipuram, Nagapura, and Basaveshwaranagar**. The entire stretch is planned as a **continuous portal substructure elevated corridor**.

- Total Length of the Main Corridor: 2.120 km
- Number of lanes: 4 lanes divided carriageway with 1.5m paved shoulder on outer side of each carriageway

3.3.3 Horizontal alignment

Horizontal alignment design has been carried out using MX Road/Open Roads software based on the topographic survey data (base plan). In general, the design standards presented in the previous section i.e., a design speed of 60 km/h or 80 km/h corresponding to a minimum horizontal curve radius of 150 m have been adhered to. However, at a few locations, site constraints necessitated deviations from these standards.

The Project Corridor sections comply with the permissible design speed requirements and do not fall below the standard. Accordingly, these sections maintain the design speed corresponding to the minimum allowable curve radius. The detailed horizontal alignment report for the proposed corridor is presented in the table below.

Table 3.1: Details of the Horizontal Alignment along Project Corridor

Sl No	Chainage	From	To	Length in m,	Radius	Direction	Speed	Remark
1	0+000							-
2	0+058	0+037	0+079	42.219	1200	Right	80 kmph	-
3	0+550	0+539	0+560	21.255	2000	Right	80 kmph	-
4	0+699	0+676	0+723	47.189	2000	Left	80 kmph	-
5	0+900	0+853	0+946	93.054	2000	Right	80 kmph	-
6	1+063	1+018	1+108	89.607	600	Right	80 kmph	-

Sl No	Chainage	From	To	Length in m,	Radius	Direction	Speed	Remark
7	1+202	1+176	1+229	53.198	2000	Right	80 kmph	-
8	1+548	1+528	1+568	40.544	2000	Left	80 kmph	-
9	1+719	1+686	1+752	65.742	2000	Right	80 kmph	-
10	1+997	1+978	2+016	38.024	2000	Left	80 kmph	-
11	2+200							-

3.3.4 Vertical alignment

Vertical alignment design has been carried out using Mx road software on existing profile generated from digital terrain model.

Table 3.1: Details of the Corridor Vertical Alignment

Section	From Km	To km	Description
West of Chord Road to Outer Ring Road Corridor	0+000	2+200	The alignment is proposed at a +1 level, portal beam for substructure designed to ensure efficient and uninterrupted traffic movement along the corridor.

3.3.5 Ramps

Ramps are a crucial component of the project, serving as the connection between the elevated corridor and the at-grade road network. While a greater number of ramps can improve accessibility for commuters wishing to use the elevated corridor, they also introduce operational challenges such as the need for acceleration and deceleration lanes, increased land requirements, and potential traffic disruptions. Given that much of the corridor passes through narrow road sections where ramp construction would necessitate acquiring large multi storey buildings, ramps have been provided only at strategically required locations based on land availability. In addition, the ramp locations have been planned in coordination with the entry and exit points of the proposed tunnel to ensure seamless integration between the two facilities. The following table presents the total number of ramps provided along the corridor.

Table 3.2: Details of entry/exit ramps along Corridor

Project Corridor	LHS Ramps		RHS Ramps		Total Ramps	
	Up	Down	Up	Down	Up	Down
NIL						

3.3.6 At grade improvement proposals

As per the terms of reference along with the proposal of elevated corridor at grade road improvement has to be proposed. Moreover due (during) to construction of elevated

corridor and by shifting of any underground utilities which are obstruction for construction of elevated corridor existing road would be damaged and restoration of same is unavoidable. Construction of piers is proposed by utilizing the median space. But a few locations existing median width is as low as 0.5m and generally 1.5m. Proposed pier width including pier protection, requiring minimum of 3.0 m. Hence due to less width of existing median, construction of piers for elevated corridor will encroach on to existing carriage way. Due to this after construction of elevated corridor at grade road carriageway will get reduced. To retain traffic lanes of existing carriageway on each side, widening of carriageway has been done by maintaining minimum width of the footpath cum drain (1.8m). Further since the speeds of city traffic is less compare to rural roads, width of each lane is proposed to be 3m. Lane width of 3m has already been followed on few city roads.

Further, it is tried to provide footpath cum drain of minimum width 1.8m throughout. Entry / Exit curves of all existing junctions are smoothened within available land. Signs and markings have been provided. Street lighting has been proposed throughout the corridors.

3.4 Summary of Proposed Cross-section

Lane width, shyness, median width and overall width of each cross section proposed are derived from IRC: SP: 90 and IRC: 86. They are presented below for ready reference and approval.

Elevated Road:

- The lane width shall be 3.5 m
- The shyness shall be 0.5 m
- Paved Shoulder shall be 1.50m
- Carriageway Width for Elevated Corridors Shall be 9.0m including Shyness and Paved Shoulder
- The median width shall be 0.610m for New Jersey Crash barrier.
- The total width of 4 lane elevated corridor is will be 19.61m

At Grade Road:

- The lane width shall be 3.0/3.5 m
- The shyness shall be 0.25/0.5 m

The proposed elevated corridors shall generally be planned as 4-lane facilities, with the exact configuration determined based on assessed traffic flow and the location of entry/exit ramps. Corresponding space standards will be adopted in accordance with IRC guidelines during detailed planning and design.

Geometric Design Standards for Project Corridors

S No.	Design Specification	Unit	Proposed Design Standards	Remarks
1	Design Speed	km/hr	60/80	IRC-86 & IRC: SP:90
	Design Speed for Ramps min.	km/hr	30-40	IRC-92
	Design Speed for loop min.	km/hr	30	IRC-92
2	PROW	m	Proposed elevated structure width plus a minimum of 1m on either for working space	Minimum RoW required for Proposed Works
3	Carriageway Width	m	Lane width is 3.5 – Elevated Road Lane width is 3.0 – At grade Road	IRC-86
4	Width of Service Road (min)	m	5.5/7.5	IRC: SP:84
5	Median Width (Elevated)	m	0.610	IRC: SP:84
	Median Width (At Grade)	m	Min 3.0	
6	Kerb Shyness	m	0.5/0.25	IRC: SP:84
7	Width of Parapet / Crash Barrier	m	0.5	IRC: SP:84
8	Width of Footpath-cum-drain	m	Minimum 1.5 wherever Land Available	IRC-103
9	Longitudinal Gradient			
	a) Max.	%	1. 3.5% for elevated road 2. 4.0% - 6.0% for ramps	IRC: SP:90
			Exceptional Cases 3. Up to 5% for Elevated Corridor 4. 7% for short lengths of Ramps	IRC:86-2018 (in constrained urban conditions)
	b) Min.	%	0.3% to 0.5%	IRC:86-2018 IRC: SP:90-2023
10	Cross Fall	%	Carriageway: 2.0/2.5	IRC: SP:90
11	Super-elevation (Maximum)	%	4.0% restricted (for Urban)	IRC: SP:90

S No.	Design Specification	Unit	Proposed Design Standards	Remarks
12	Minimum Radius of Curvature	m	150/265 (60/80kmph)	IRC-86
13	Safe Stopping Sight Distance	m	80/120 (60/80kmph)	IRC: SP:90
14	Minimum VC Length	m	40/50	IRC-86
15.	Speed change lanes	m		
	Acceleration lane	m	250 (desirable)/180 (min.) *	IRC-92
	Deceleration lane	m	120 (desirable)/90 (min.) *	IRC-92
16.	Weaving length	m	300 (desirable)/200 (min.) *	IRC-92
17.	Lateral clearance	m	Min. 1.0	IRC: SP:90
18.	Vertical clearance	m	5.5/6.525	IRC: SP:90
* Depending upon the availability of the land.				

3.5 Pavement Design

Designs for new pavement and overlays shall be produced in accordance with IRC codes. Generally, the recommendation for rehabilitating the existing pavement depends upon the functional condition, structural condition of the pavement, Subgrade type, Subgrade strength and characteristics. Once the improvement proposals are finalized, the flexible pavement composition shall be designed as per IRC: 37 and concrete pavement shall be designed as per IRC 58 and white topping as per IRC SP 76.

3.6 Design of Structures

3.6.1 Design Assumptions

The design would be carried out using the limit state design philosophy satisfying the requirements of IRC-112:2020. The structures would be designed to meet both the ultimate and serviceability requirements of the code.

Ultimate limit state: This covers static equilibrium and failure of structural elements or structure as a whole when acted upon by ultimate design load.

Serviceability limit state: This deals with the condition of structure subjected to serviceability design loads. These conditions include level of internal stress, fatigue failure, deflection, cracking and discomfort by vibrations.

List of Design Standards

Sl. No.	Description		Standard
1	**Exposure Condition:** As the general environment condition is dry for project location, Exposure condition is classified as moderate & accordingly clear cover is provided for structural components as per IRC: 112-2020. Minimum clear cover to reinforcement is given below.		
	i	Superstructure	40mm
	ii	Crash Barrier	40mm
	iii	Substructure	50mm
	iv	Pre-stressing cable duct	75/90mm
	v	Pre-cast elements	40mm
	vi	Foundations	75mm
2	**Grade of Steel**		
	i	HYSD bars	Fe550
	ii	Structural Steel	E250
3	**Grade of Concrete**		
	i	Prestressed Concrete I Girder	M55
	ii	RCC Deck slab over PSC Girder	M55
	iii	Strutted Box ((UHPFRC)	M150
	iv	PSC Pier Cap	M55
	v	Bearing Pedestal	M40
	vi	RCC Abutment, Abutment cap, Dirt wall.	M35
	vii	Pile/Pile cap	M35
	viii	Pile foundation	M35
	ix	Crash Barrier	M40
	x	Approach slab	M30
	xi	Leveling course	M15

The design of the elevated corridor will be governed by a comprehensive design philosophy that addresses all structural components including the superstructure, substructure and foundations. This philosophy will be based on relevant IRC Codes, MoRTH guidelines,

and BIS standards. In areas where Indian codes lack guidance, international standards such as AASHTO, French standard and Eurocodes along with sound engineering judgment, will be adopted. Special considerations will be given for segments crossing railway or metro lines, following specifications laid down by Indian Railways or BMRCL. Final structural decisions such as shape, type, and configuration will rely on extensive data collection, including geotechnical surveys, traffic patterns, and utility mapping, to ensure the design suits local site conditions. Structures will be designed for a 100-year service life, with appropriate measures for exposure, durability, and replaceability of certain elements.

Design and analysis will follow a limit state approach, using codes such as IRC:6-2017 for loadings and combinations and tools like STAAD Pro, for global and local structural modelling. Load considerations include dead load, superimposed dead load, IRC Class 70R/Class A vehicular loads, braking, centrifugal, seismic, wind, thermal, and construction-related forces. Accidental and collision loads, as well as long-term effects like creep, shrinkage, settlement, and temperature gradients, will be addressed as per IRC provisions. Material specifications include M35/55 and M150 grade of concrete and Fe-550 reinforcement steel with appropriate cover to reinforcement. Other essential design elements like bearings, expansion joints, wearing courses, and approach slabs will comply with relevant IRC and MoRTH guidelines to ensure safety, serviceability, and long-term durability of the elevated corridor structure

3.6.2 Design Codes

The IRC codes/Standards/Act, MoRT&H Publications, IS & BIS codes shall be followed in the project. Design of Elevated corridor shall be done in accordance with the provisions of the following Codes:

List of Design codes and Standards

IRC CODES	
IRC:5 2015	Standard Specifications and Code of Practice for Road Bridges Section: I - General Features of Design (8th Revision)
IRC:6 2017	Standard Specifications and Code of Practice for Road Bridges Section: II - Load and Stresses (Revised Edition)
IRC:22 2014	Standard Specifications and Code of Practice for Road Bridges Section - VI Composite Construction (Limit State Design) - (3rd Revision)
IRC:24 2010	Standard Specifications and Code of Practice for Road Bridges Section - V Steel Road Bridges (Limit State Design) - (3rd Revision)
IRC:78 2020	Standard Specifications and Code of Practice for Road Bridges Section: VII – Foundations and Substructures (Revised Edition)
IRC:83(Part I) 2014	Standard Specifications and Code of Practice for Road Bridges Section: IX – Bearings (Rocker & Roller Bearings) – (2nd Revision)
IRC:83(Part II) 2014	Standard Specifications and Code of Practice for Road Bridges Section: IX – Bearings (Elastomeric Bearings)
IRC:83 (Part III) 2014	Standard Specifications and Code of Practice for Road Bridges Section: IX – Bearings (Spherical and Cylindrical Bearings)
IRC:83 (Part IV) 2014	Standard Specifications and Code of Practice for Road Bridges Section: IX – Bearings (POT, POT-cum-PTFE, Pin and Metallic Guide Bearings)
IRC:87 2019	Design and Erection of Formwork, False-work and Temporary Structures (2nd Revision)
IRC: SP:50 2013	Guidelines for Urban Drainage (Ist Revision)
IRC: SP:66 2016	Guidelines for Design of Continuous Bridges
IRC: SP:69 2011	Guidelines and Specifications for Expansion Joints
IRC: SP:090 2015	Manual for Grade Separators and Elevated Structures
IRC: SP:102 2015	Guidelines for Design and Construction of Reinforced Soil Walls

IS CODES	
IS: 269-1976	Specs for Ordinary and Low Heat Portland cement
IS: 432-1982	Specs for Mild Steel & medium tensile steel bars

IS: 456-2000	Code of Practice for Plain and Reinforced Concrete - based essentially on CP-110
IS: 1786-1985	Specs. for High Strength Deformed steel bars and wires for concrete reinforcement
IS: 1893(Part 1)-2002	Criteria for Earthquake Resistant Design of structures
IS: 1904-1986	Design and Construction of Foundation in soils: General Requirements
IS: 2502-1963	Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement
IS: 2911	Code of Practice for Design & Constr. of Pile Foundations Part 4 Load test on Piles
IS: 9103-1999	Specifications for Admixtures for Concrete
IS: 12269-1987	Specifications for 53 Grade Ordinary Portland cement
IS: 14268-1995	Uncoated Stress Relived Low Relaxation Seven-ply Strands for Prestressed Concrete
IS: 14593-1998	Design and Construction of Bored Cast-In-Situ Piles
	Founded on Rocks-Guidelines

INTERNATIONAL CODES	
BS: 4447-1983	Specifications for the Performance of Prestressing Anchorages for Post-Tensioned Construction
BS: 4486	Specifications for High Tensile Steel bars used for Prestressing
BS: 5400	Code of Practice for Design of Concrete Bridges Part-4-1990
BS: 5400	Code of Practice for Fatigue Part-10-1990
BS: 8006	Code of Practice for Strengthened Reinforced soils and other fills-1995
BS: 8007-1987	Design of Concrete Structures for Retaining Aqueous Liquids
NF P 18-710	National addition to Eurocode 2 — Design of concrete structures: specific rules for Ultra-High-Performance Fibre-Reinforced Concrete (UHPFRC)
BD 37/01	Loads for Highway Bridges
BD 58/94	The Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing

INTERNATIONAL CODES	
ACI 358.1R-92	(American Concrete Institute) for assessment of dynamic impact for transit Guideways.
AASHTO-1996	AASHTO LRFD Bridge Design Specifications–Second Edition 1998
Eurocode 0	Basis of Structural Design
Eurocode 1	Actions on Structures-Part2: Traffic Loads On bridges
Eurocode 2	Design of Concrete Structures-Part 2 Concrete Bridges-Design and Detailing Rules

Any Specific Requirement of the Project as per TOR shall also be made to other Standard Engineering Practices as and when required. All calculations and drawings shall be made in metric (SI) system. All latest revision of codes shall be followed.

3.6.3 Material Standards

i) Conventional Concrete

Cement

For construction of structures 43 grade ordinary Portland cement conforming to IS: 269 and 53 grade ordinary Portland cement conforming to IS: 269 shall be used. Other types of cement mentioned in IRC-112:2020 Clause 18.4.1 may be used for special requirement of structure with the approval of Engineer in charge.

Admixtures

To improve workability of concrete, admixtures conforming to IS: 9103 shall be used.

Aggregates

Aggregates shall consist of clean, hard, strong, dense, non-porous and durable crushed stone for coarse aggregates and natural particles for sand. The aggregates shall conform to IS: 383 and shall be tested to conform to IS: 2386 parts I to VIII. Size of coarse aggregate shall be selected as per mix design requirement.

Water

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. The pH value of water shall not be less than 6. Other permissible limits for solids in water are given in Table-18.6 of IRC: 112-2020.

Concrete

The grade of concrete shall be as per design requirement and mentioned in execution drawings for each component of the structure. Cement and water content shall be as per mix design requirement; however minimum grade of concrete, minimum cement content and maximum water cement ratio shall be conforming to Table–14.2 of IRC: 112-2020for Severe exposure condition. The cement content shall not exceed 450 kg/m^3 of concrete as per Clause 14.3.2.5 of IRC: 112-2020.

Permissible stresses in concrete -

- Under rare combination of loads maximum compressive stress shall be limited to **$0.48f_{ck}$**
- Under Quasi permanent combination of loads maximum compressive stress shall be limited to **$0.36f_{ck}$**
- The parabolic rectangular stress-strain block is of general validity for all design situations. However, simplified equivalent stress blocks such as rectangle or bilinear may be used for design purposes where the net results are sufficiently accurate.
- Partial safety factor used for concrete in limit state design is
    - γ_m - 1.5 for basic and seismic combination
    - γ_m - 1.2 for accidental combination.

ii) Ultra-High Performance Fiber Reinforced Concrete

Ultra-High-Performance Fiber-Reinforced Concrete (UHPFRC) is an advanced class of concrete that exhibits exceptional mechanical and durability properties compared to conventional concrete. It is a cementitious composite material that combines ultra-high compressive strength, enhanced ductility, very low permeability, and improved impact and fatigue resistance, primarily due to the incorporation of fine materials and steel fibers in the mix.

Materials

Cement

For construction of structures 43 grade ordinary Portland cement conforming to IS: 269 and 53 grade ordinary Portland cement conforming to IS: 269 shall be used. Other types of cement mentioned in IRC-112:2020 Clause 18.4.1 may be used for special requirement of structure with the approval of Engineer in charge.

Admixtures

To improve workability of concrete, admixtures conforming to IS: 9103 shall be used.

Fine Silica Sand

Aggregates shall consist of clean, hard, strong, dense, non-porous and durable crushed stone for coarse aggregates and natural particles for sand. The aggregates shall conform to IS: 383 and shall be tested to conform to IS: 2386 parts I to VIII. Size of coarse aggregate shall be selected as per mix design requirement.

Ice flakes

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. The pH value of water shall not be less than 6. Other permissible limits for solids in water are given in Table-18.6 of IRC: 112-2020.

iii) Reinforcement

Deformed or TMT reinforcement bar conforming to IS: 1786 shall be used for components of the structures. The reinforcement grade shall be Fe550.

Permissible stresses in Reinforcing steel -

- For checking serviceability criteria permissible stress in reinforcement should be limited to 300 MPa or 0.6 Fy under rare combinations as per IRC -112:2019.
- Partial safety factor used for reinforcement in limit state method for Basic and seismic combination is 1.15 or permissible stress is limited to 0.87 Fy

Prestressing Steel

Prestressing tendons normally take the form of separate wires, wires spun together helically to form strands or bars. For pre-tensioned steel, wires, strands and occasionally bars are used, simply to permit the concrete to bond directly to them; when post-tensioning is used, it is common practice to group the separate tendons together, so as to reduce the number of anchorages and ducts required to accommodate them. When grouped in this way, the tendons in each duct are usually termed a cable.

Uncoated stress relieved low relaxation steel conforming to IS: 14268 shall only be used for pre- stressing steel so as to reduce losses due to relaxation. Data in respect of modulus of elasticity, relaxation loss at 1000 hours, minimum ultimate tensile strength, stress-strain curve etc. shall necessarily be obtained from manufacturers. Pre-stressing

steel shall be subjected to acceptance tests prior to actual use on the works (guidance may be taken from BS: 4447). The modulus of elasticity value, as per acceptance tests, shall conform to the design value which shall be within a range not more than 5 percent between the maximum and minimum.

Many cables with different arrangements of wires and strands and different methods of anchorage are available as pre-stressing steel. So, type and size of cable and methods of anchorage shall be decided on the basis of design requirement.

Permissible stresses in Prestressed Concrete -

For Prestressed concrete structures under the frequent combination of action and prestressing force, only compressive stresses allowed at the extreme concrete fibers, under Serviceability Limit State.

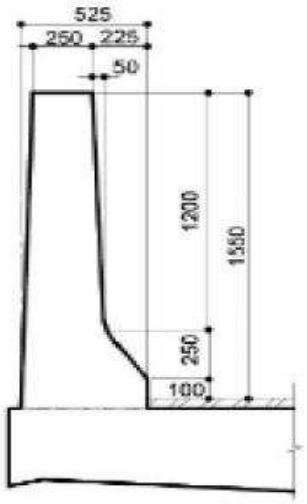
Sheathing

The duct or sheath for cables to be used of Corrugated HDPE having coefficient of friction as 0.17 and wobble coefficient per meter length of steel 0.0020. The thickness of sheathing shall be as specified in clause 13.4.3 of IRC: 112-2020.

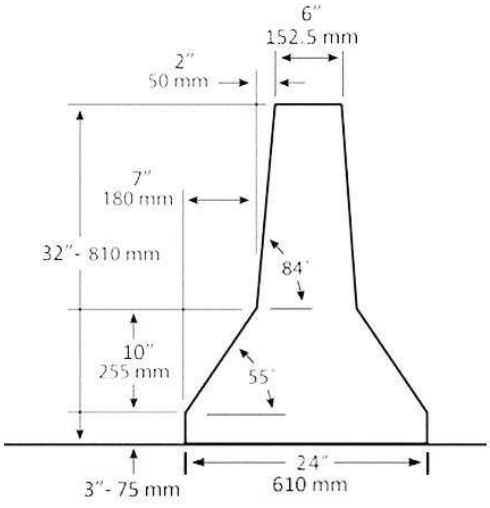
3.6.4 Miscellaneous Items

Crash Barriers

Suitably designed crash barriers shall be provided at the situations to safeguard against errant vehicles:



Crash Barrier @ Edge



New Jersey Crash Barrier @ Median

The type of crash barriers is provided according to their applications summarized below.

P-1: Normal Containment. This shall be provided on the Bridges/Flyovers/Overpasses for National Highways.

The other structures which cross the national highway shall be provided with P-2: Low Containment.

The Crash barrier has been provided according to IRC: 5-2015. The typical detail of the crash barrier is as shown.

Expansion Joints

Expansion joint shall be provided as per IRC: SP: 69-2011.These shall conform to Section 2600 Technical Specification of MORTH. Types of expansion joint based upon the length of span and movements are as given below:

Type of Expansion Joints

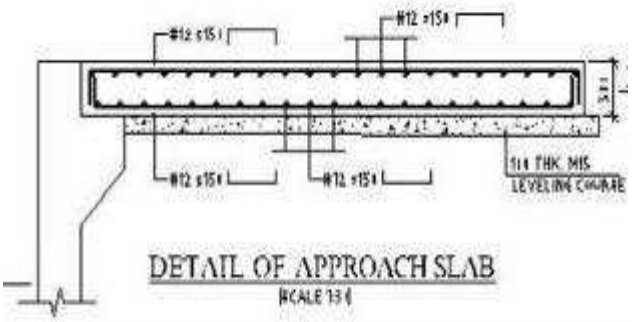
Sl. No.	Span	Expansion Joints
1	Spans more than 20m	Strip Seal type expansion joints

Wearing Course

50mm thick bituminous wearing coat shall comprise of Bituminous Concrete. Before laying wearing coat the deck surface shall be thoroughly cleaned and tack coat shall be applied. The construction operations and bituminous mixes and tack coat shall conform to Section 500 of the MoRTH Specifications.

Edge Treatment

A drip course of 25mm shall be provided at the edge and bottom of the cantilever of the superstructure to barricade the flow into the base of superstructure.



Approaches

The approaches on the either side of the viaduct spans would generally have earth retaining structures such as RE wall with gap slab or approach slab.

Lamp Post Fixtures and Utilities

The standard fixture details shall be used either from the middle of crash barrier or from the cantilever slab protruding from the crash barrier or median verge.

100mm diameter pipes shall be provided in the raised footpath or in crash barrier to facilitate the utilities running along the bridge.

Approach Slab

Reinforced concrete approach slabs, 3.5 m long and 300 mm thick, in M30 grade concrete at either end of the bridge, will be provided. One end will be supported on the reinforced concrete bracket projecting from the dirt wall and the other end resting over the soil, in accordance with the guidelines issued by MoRT&H. A leveling course, 150 mm thick, in M-15 grade concrete will be laid under the approach slabs as per MOST standard.

Drainage Spouts

Drainage spouts will be provided in accordance with MOST standard plans. The minimum spacing shall be kept preferably as 5.0m c/c which may be adjusted to suit span length.

Sprinkler type drainage spout to be used for down take at pier location.

3.6.5 Loading

Dead Load (DL)

The dead load i.e., the self-weight of the superstructure, substructure and foundations, backfill will be considered as per the Cl. 203 of IRC: 6 -2017 and are summarized as below:

Reinforced Cement Concrete	- 2.5 t/m^3
Prestressed Cement Concrete	- 2.5 t/m^3
Asphaltic Concrete	- 2.2 t/m^3
Earth Compacted dry	- 2.0 t/m^3

Superimposed Dead Load (SIDL)

SIDL is defined as self-weight of non-structural component such as surfacing and other utilities carried by the bridge / structure. Crash barrier is adopted as per IRC: 5-2015.

Following permanent elements loads will be considered in the category of SIDL:

- For design purposes weight of the asphaltic wearing course shall be considered as 2.2 kN/m^2 (with future overlay)
- Outer crash barrier with area of 0.514m^2 with 1.55m height will be considered for both unsupported longitudinal edges of the deck.
- The weight of known utilities carried on the elevated structure shall be taken into consideration. As future utilities are unknown then an allowance of 1 kN/m per carriageway shall be considered for this purpose.
- New Jersey crash barrier with base width of 0.61m will be considered at the median portion.

Seismic Design and Detailing

As per the seismic map given in IRC: 6-2017, the project corridors lie in Zone-II. Therefore, all structures will be designed for basic seismic condition of Zone-II. Seismic force shall be calculated in accordance with the IRC: 6-2014.

$$F_{eq} = A_h \text{ (Dead Load + Appropriate Live Load)}$$

Where,

Ah = Horizontal Seismic Coefficient = $\left(\frac{Z}{2}\right)$ X(I)X $\left(\frac{Sa}{g}\right)$

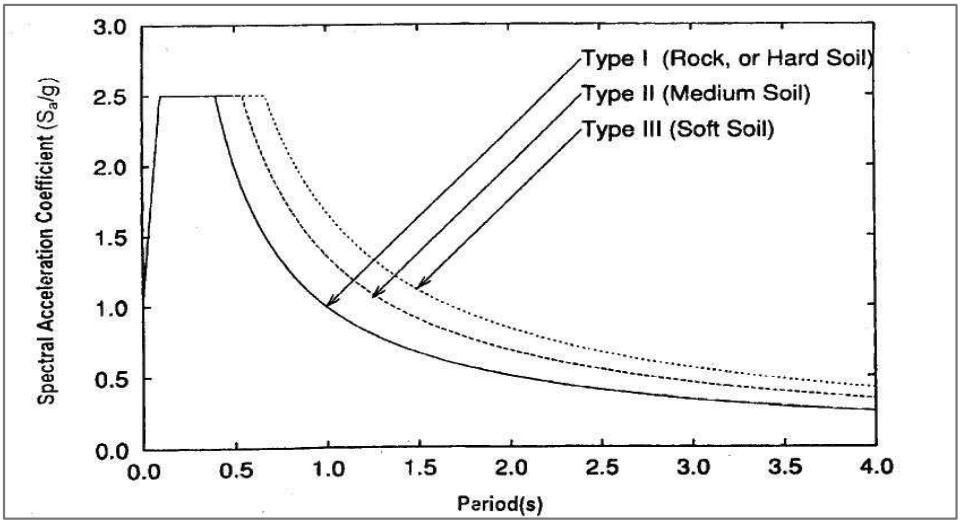
Z = Zone factor shall be taken from IRC: 6 – 2014

I = Importance factor shall be taken from IRC: 6 – 2014.

R = Response reduction factor shall be taken from IRC: 6 – 2014

T = Fundamental period of the bridge in seconds in horizontal vibrations

$\frac{Sa}{g}$ = Average response acceleration coefficient depending upon fundamental period of Vibration.



Response Spectra

Design response spectra

In accordance with provision of Cl. 219.4 of IRC:6-2017, the following seismic combinations will be considered for the seismic design loading on the structure:

EQ = EQx + 0.3 EQy

EQ = EQy + 0.3 EQx

The seismic force (modal mass) due to live load shall not be considered when acting in the direction of traffic, but shall be considered in the direction perpendicular to traffic. Parts of the structure embedded in soil shall not be considered to produce any seismic forces. Only 20% of Live Load on the deck will be considered in transverse seismic case.

Seismic effect on the structure will be determined by multi modal-dynamic analysis of the structure. Dynamic analysis is performed under three stages. The first being modal analysis, which includes determinations of natural frequencies, mode shapes and hence the participation factors and the spatial distribution of the masses for each mode. The second stage is the calculation of the spatial distribution of the effective earth quake forces based on the concept of Response Spectrum. And in the third step, the evaluation of earthquake forces in different components of the structure.

Differential Settlement

If the riding quality permits, clause 706.3.2.1 of IRC: 78-2014 specify that the calculated differential settlement between the foundations of simply supported span shall not exceed L / 400 of the distance between the foundations, where L is distance between two

foundations. In case of structure sensitive to differential settlement such as continuous structures the value of differential settlement shall be taken as 10mm.

If required, differential settlement shall also be considered as a long-term effect developing gradually and its effect shall be considered as being modified by concrete creep, however the maximum reduction due to creep shall be limited to 40%.

Temperature Gradient

There are two temperature effects that cause forces in a continuous bridge viz. temperature gradient in the girder and a uniform temperature range applied to the entire structure.

Uniform temperature (TU)

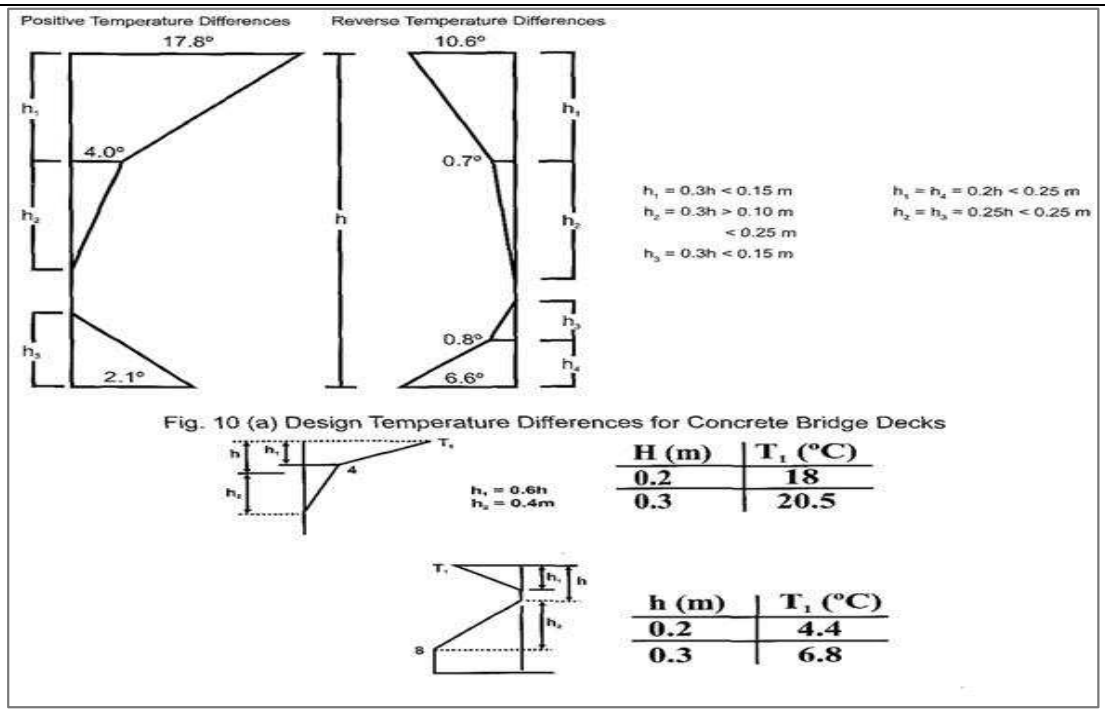
Minimum and maximum air shade temperatures in the project corridor are equal to +0°C & 45.0°C respectively. Therefore, the mean of maximum and minimum air shade temperature is equal to 22.5°C.

As the bridge location has a difference between maximum and minimum shade temperature greater than 20 °C; the bridge temperature to be assumed when the structure is effectively restrained as per the table shown in IRC-6 § 215.2, is equal to mean of maximum and minimum air shade temperature +10°C whichever is critical, which corresponds in this case to 22.5 °C or 32.5 °C.

Then, lowering of temperature will be in the range of 32.5 - 0 = 32.5°C and temperature increase equal to 45.0 – 22.5 = 22.5 °C. Uniform temperature variation is considered as a long-term loading. The elastic modulus for uniform temperature effects will be taken as 0.5 times the instantaneous elastic modulus.

Temperature Gradient (TG)

Positive and reverse temperature differences have to be considered as a short-term effect for the superstructures of main bridge only. The non-linear thermic diagram defined in IRC 6-2017 of Clause 215.3 will be used.



Temperature Difference across Steel and Composite Section

Construction Loads

Construction loads and construction load combinations shall be considered as per provision of AASHRO LRFD Section 5.14.2.3.2

Construction agency will be responsible for ensuring that his proposed handling, erection methods and sequences of construction do not overstress the permanent works. Stability during Erection: § 5.14.2.4.4 of AASHTO-LRFD Specifications

During all stages of erection longitudinal and transverse stability of the incomplete structure shall be ensured and a minimum stability factor of 1.5 under the worst combinations of dead loads, construction loads, loads from erection equipment and wind load shall be required.

- A construction live load (CLL) of 50 kg/m² shall be considered during cantilever erection.
- Weight of the lifting frame (CE) will be taken as per manufacturer's data for different segment sizes
- An impact (IE) of 10 % shall be considered for the moving construction loads

Centrifugal Forces

Centrifugal forces are considered for spans in curved portion as per IRC 6-2017. Centrifugal forces shall be determined from following formula:

$$C = WV^2/127R$$

Where,

C =Centrifugal force acting normal to the traffic.

W = Live load (tonnes/m)

V= Design speed of vehicles (Km/ hour)

R = Radius of curvature (m)

The centrifugal force will be considered to act at 1.20m above the formation level of the elevated structure in the transverse direction. No impact value on carriageway live load has been considered for calculating the centrifugal force.

Wind loads

Wind load on structure shall be considered as per clause 209 of IRC: 6-2017.

A lateral wind force against moving live loads shall be considered as acting at 1.5m above the roadway and shall be assumed equal to 300 kg/m.

Vehicular Collision Load:

Effect of Vehicular collision load shall be in accordance with clause 222 of IRC: 6-2014. Structures which are within 4.5 m away from carriageway shall be considered for collision loads. Collision load shall be taken as an accidental load. These loads shall be as per table 11 of IRC: 6-2017.

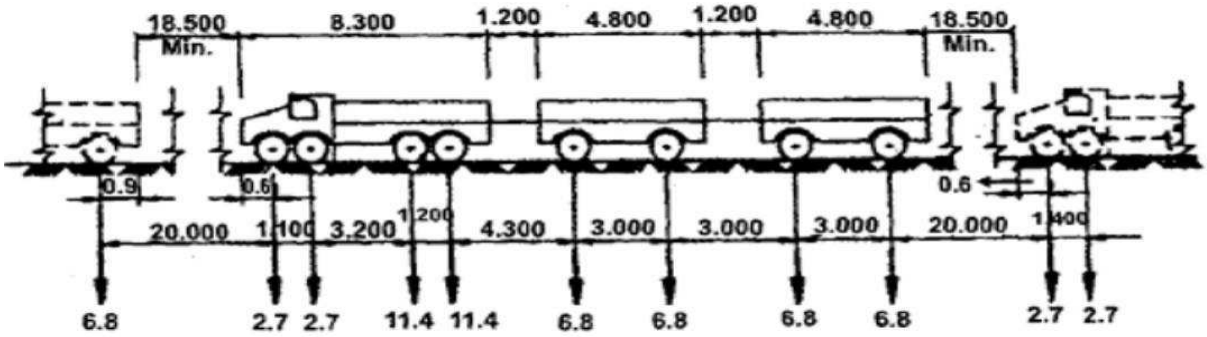
Accidental load on Crash Barriers

Loads coming from crash barriers of P-1 category (Refer IRC: 6-2014), will be considered for the transverse analysis of the superstructure. The transverse bending moment transmitted by the base of the barrier is equal to 15kN/m.

Live Load Combinations

Live load combinations mentioned in IRC: 6-2017 Table-6 shall be followed as per relevant carriageway width.

All proposed elevated structures with single or divided carriageway will be designed for governing effect of IRC loadings (Class 70R and Class A) with appropriate lane reduction factor as specified in IRC: 6-2017. The above loads will be increased by appropriate impact factors as per provision of Cl: 208 of IRC: 6-2017.

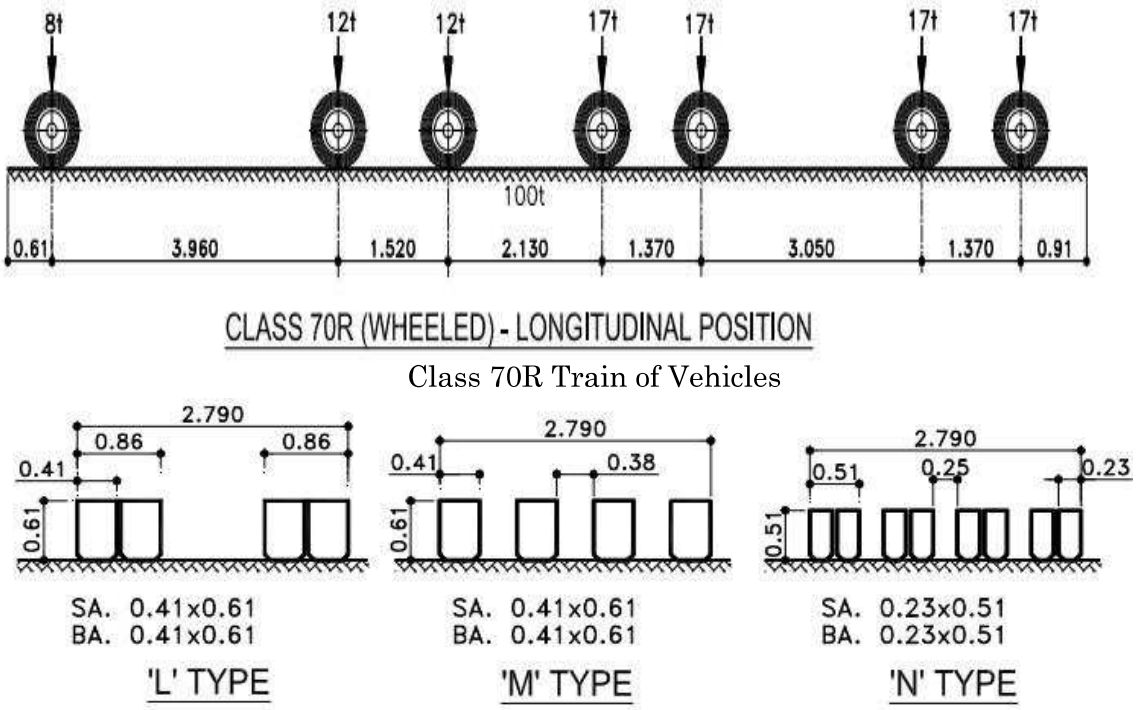


Class A Train of Vehicles

Class-A trains are spaced every 20m whereas 70R are spaced every 30m between axles for wheeled vehicles, and every 30 m from tail to nose for tracked vehicles.

For Local Live Load Analysis (LL)

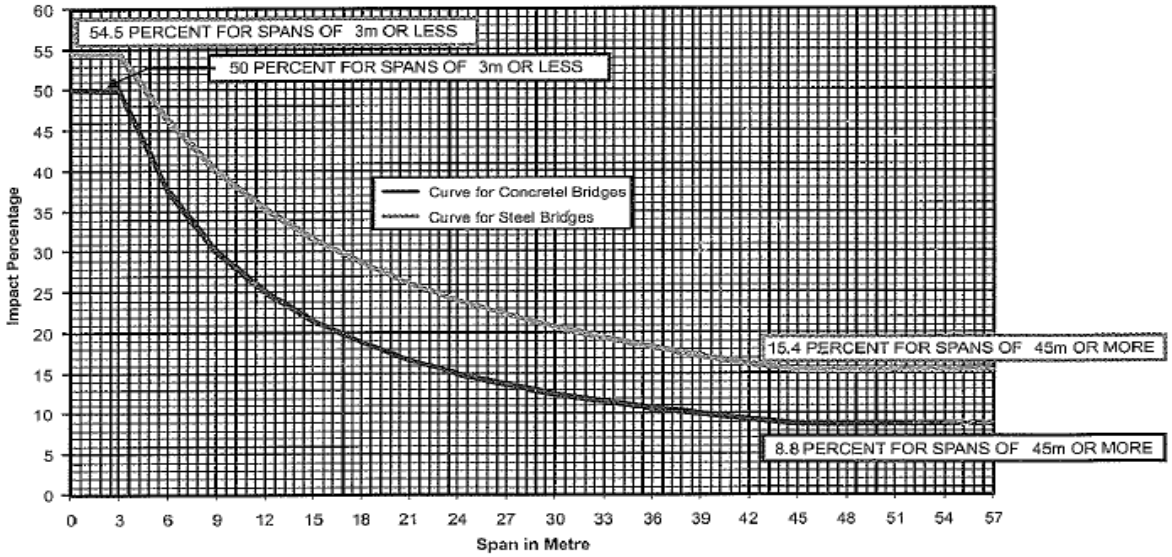
Load cases of single axle of 20t and a bogie of 40 t (two axles spaced at 1220 mm) are to be considered for the local analysis of the deck. Transverse spacing of the wheels of the axle or the bogie, and wheel impact shall be as per the following sketch:



Class 70R Train of Vehicles

Traverse Spacing of the Wheels

Effect of Vehicle Impact for longitudinal and transverse analysis (IM) Vertical impact for Class A loading shall be as per figure given below:



Vehicle Impact percentage for IRC Class A

Class 70 R – wheeled vehicles, impact shall be taken equal to 25 % for spans less than 12m, and in accordance with above figure for spans in excess of 12 m.

For Class 70 R – tracked vehicles, impact shall be taken equal to 25 % for spans up to 5 m, linearly reducing to 10% for spans of 9m. 10% for spans up to 40 m and in accordance with above figure for spans in excess of 40 m.

As per Cl. 4. (II) of IRC: SP: 66-2005, impact factor for the continuous bridge of unequal spans, the least effective span will be considered for determining the Impact Factor.

Longitudinal force of Live Load due to Braking (BR):

For the first two loaded lanes, braking force will be considered 20% of the vertical load of the first train load without reduction plus 10% for the succeeding trains. From the third loaded lane and succeeding lanes, only 5% of the vertical load of each lane shall be considered for all additional lanes.

Total braking force will be computed based on the number of design lanes in the same direction. Braking forces will not be increased for impact allowance, assumed to act horizontally at a height of 1.2m above the roadway surface, and distributed equally on all bearings.

Shrinkage and Creep

Shrinkage and creep coefficient to be calculated as per IRC 112:2020 and its effect in long term loading to be incorporated.

Following engineering calculations of time dependent effects on concrete shall be considered as given below

- For shrinkage calculations purposes, the average humidity ratio shall be taken at 75%.
- Creep calculations will be done for 100 years horizon.
- Time dependent effects of creep and shrinkage for precast and in-situ portion of the structure shall be computed using ACI-209 model.

  A range of ± 20% shall be considered on the creep factor for both pre-cast and in-situ design

Bearing Replacement

The superstructure deck, substructure and bearings shall be designed and detailed to permit future bearing replacement of each and every bearing and jacking points shall be clearly shown on the drawings.

- No reduction in traffic loading shall be considered during bearing replacement.
- A maximum jacking movement of 10mm shall be assumed for bearing replacement.

Combination of Loads for Design

Annexure-B to Cl.202.3 of IRC: 6-2017, for Limit State Design Approach, load combination as shown in Annex B shall be adopted.

Combination of Loads for under Ultimate Limit State

- For checking the equilibrium of the structure, under **ULS Basic Combination**, the partial safety factor for loads shown in Column No. 2 or 3 under Table 3.1 shall be adopted.
- For checking the structural strength of the structure, under **ULS Basic Combination**, the partial safety factor for loads shown in Column No. 2 under Table 3.2 shall be adopted.
- **Under ULS Accidental Combination,** for checking the equilibrium of the structure, the partial safety factor for loads shown in Column No. 4 or 5 under Table 3.1 and for checking the structural strength, the partial safety factor for loads shown in Column No. 3 under Table 3.2 shall be adopted.
- **Under ULS Seismic Combination**, for checking the equilibrium of the structure, the partial safety factor for loads shown in Column No. 6 or 7 under Table 3.1 and for checking the structural strength, the partial safety factor for loads shown in

Column No. 4 under Table 3.2 shall be adopted.

Combination of Loads for under Serviceability Limit State

The serviceability limit state check shall be carried out in order to have control on stress, deflection, vibration, crack width, settlement and to estimate shrinkage and creep effects. It shall be ensured that the design value obtained by using the appropriate combination shall be less than the limiting value of serviceability criterion as per the relevant code. The rare combination of loads shall be used for checking the stress limit. The frequent combination of loads shall be used for checking the deflection, vibration and crack width. The quasi-permanent combination of loads shall be used for checking the settlement, shrinkage creep effects and the permanent stress in concrete.

- **Under SLS Rare Combination,** for checking the stress limits, the partial safety factor for loads shown in Column No. 2 under Table 3.3 shall be adopted.
- **Under SLS Frequent Combination,** for checking the deflection, vibration and crack width in pre-stressed concrete structures, partial safety factor for loads shown in column no. 3 under Table 3.3 shall be adopted.
- **Under SLS Quasi-Permanent Combination,** for checking the crack width in RCC structures, settlement, creep effects and to estimate the permanent stress in the structure, partial safety factor for loads shown in Column No. 4 under Table 3.3 shall be adopted.

The permissible stresses for pre-stressing and reinforcement shall be considered as per Chapter 12 of IRC:112-2020.

- Allowable compressive stresses in concrete under rare combination of loads shall be limited to 0.48fck.
- Allowable compressive stresses in concrete under quasi permanent combination of loads shall be limited to 0.36fck.
- Allowable stresses in reinforcement for reinforced concrete structures under rare and quasi permanent combination of loads shall be limited to 300MPa without fatigue check
- Crack width calculations shall be done as per Cl. 12.3.4 of IRC:112-2020. The crack width shall be limited to 0.3 mm for RC members & pre-stressed with unbounded tendons under quasi-permanent load combination and 0.2 mm for pre-stressed

members with bonded tendons under frequent load combination as per Table 12.1 of IRC: 112-2020.

3.7 Construction Methodology

3.7.1 PSC I-Girder

1. Casting and Transport

- **Precast I-Girder Casting Yard**: Girders are cast in a controlled yard (typically adjacent to the site), using precast beds, formwork, and tensioning jigs. Concrete mix design, reinforcement layout, and tendon placement are done per design specifications such as IRC and IS codes. After curing, these precast I-girders are transported to the site using specialized trailers.

2. Girder Erection and Launching

- **Erection**: Girders are placed onto piers or bearings using either cranes or a **launching gantry**, a specialized bridge-building machine that lifts and systematically places the girders span by span.
- **Launching Gantry Use**: This method enhances safety and minimizes traffic disruption on site.
- **Support Setup**: Pre-installed bearings and pedestals (e.g., pot bearings) are ready to receive the girders and transmit loads properly.

3. Post-Tensioning and Stressing Sequence

- Once positioned, girders undergo **post-tensioning**—tensioning of tendons to compress the concrete and improve capacity.
- A typical stress sequence includes:
    1. Cable/sheathing layout and profiling.
    2. Installation of end blocks or tube units.
    3. Grouting of ducts (if applicable).
    4. Stressing using wedges and bearing plates.
    5. Cutting and sealing tendon ends.
    6. Grouting of the stressed tendons to protect against corrosion.

- Proper sequence is key: for example, in span-by-span or cantilever bridges, tendons are partially stressed first to offset dead loads before removing temporary supports—as emphasized by construction professionals:

4. Stress Loss Management

- Tendon stress losses (due to creep, shrinkage, relaxation) are substantial. Engineers often apply initial overstress or schedule multiple stressing events (e.g., at placement, after deck casting, after overlay) to compensate for these losses.

5. Joint Closure and Composite Action

- Diaphragms or slab diaphragms (e.g., in cast-in-situ closures) connect girders transversely, providing structural continuity and stiffness. After placement, these connections and deck slabs complete the composite superstructure.

6. Quality Control and Avoiding Defects

- Watch out for issues like **cold joints**: If the concrete is poured in lifts and joints are not roughened, cracks can appear after formwork removal even before stressing. As one engineer pointed out:
- **Alignment tolerances** during girder placement are critical-errors can cause lateral sweeps or misalignment, impairing structural integrity.

7. Finalization

- After stressing and connection, final checks ensure proper concrete curing, compensation for stress losses, alignment accuracy, and joint performance before traffic loading begins.

3.7.2 UHPFRC Strutted Box

A strutted box girder involves using specialized formwork to mold hollow, box-shaped concrete segments either cast-in-place or precast used frequently in urban flyovers, bridges, and viaducts.

Construction methodology of strutted box girders

UHPFRC Strutted Box Construction Methodology in Urban Areas

1. **Site Investigation & Planning**
    - Conduct detailed topographical surveys and underground utility mapping.
    - Assess traffic patterns and space constraints.

- Identify staging areas for equipment and precast elements.

2. **Design Finalization**
   - Develop structural design optimized for UHPFRC properties (high strength, slenderness).
   - Minimize section sizes and self-weight for ease of transportation and erection.
3. **Precasting of Elements**
   - Precast the UHPFRC box segments and struts in a controlled casting yard.
   - Use steel molds to achieve high dimensional accuracy.
   - Incorporate ducts, inserts, and post-tensioning provisions during casting.
4. **Curing and Quality Control**
   - Apply heat or steam curing to achieve early strength gain.
   - Perform quality checks including compressive strength, fiber dispersion, and surface finish.
5. **Transportation & Handling**
   - Transport precast segments during non-peak hours to minimize urban disruption.
   - Use self-propelled modular transporters (SPMTs) or trailers suitable for city movement.
6. **Erection of Structure**
   - Use cranes or launching girders for placing segments, depending on span and site access.
   - Install struts and box segments in sequence to maintain balance and stability.
7. **Post-Tensioning & Jointing**
   - Perform post-tensioning through internal ducts once all segments are in position.
   - Seal segmental joints with epoxy or grout.
   - Execute closure pours (if needed) using UHPFRC for continuity.
8. **Minimizing Falsework**
   - Adopt balanced cantilever or span-by-span construction to reduce temporary supports.
   - Utilize pier brackets or temporary steel supports where necessary.
9. **Finishing Works**

- Apply limited waterproofing due to UHPFRC's dense matrix and durability.
- Install parapets, barriers, and wearing course as per project specifications.

3.8 Design Methodology

3.8.1 Pile Foundation

In general, the design of pile and pile cap shall conform to provisions of IRC: 78-2014. The various specific assumptions to be made for the design of pile and pile cap shall be as follows:

The vertical load carrying capacity of the pile shall be determined based on static formula given in Appendix-5 of IRC: 78-2014. The following limiting values shall be considered for computation of safe load:

- Results of sub-soil investigation shall be used for adopting the value of angle of internal friction "Φ" and cohesion "C" of the soil.
- Angle of wall friction "δ" to be taken as equal to Angle of internal friction "Φ".
- The entire overburden soil shall be assumed fully submerged for the purpose of calculation of safe load.
- Maximum overburden pressure at the bottom of pile for the purpose of calculation of shaft friction and end bearing shall be limited to 20 times the diameter of the pile.
- Factory of safety shall be taken as 2.5 of piles in soil.

The vertical load carrying capacity as calculated by static formula shall be verified by conducting initial load tests on piles conforming to IS: 2911 (Part 4).

The lateral load carrying capacity of the pile shall be determined by using empirical formula given in IS:2911 (Part-1/Sec-2) by limiting the lateral deflection of 1% of Pile dia. at cut off level considering it as fixed headed pile under normal conditions. The capacity so evaluated will be used purely for the purpose of arriving at the upper bound of lateral load capacity. This deflection limitation will not be applicable in load combination with seismic conditions for which the resulting stresses and the structural capacity of the section would be the governing criteria.

Soil stiffness for lateral loads shall be taken from IS:2911 (Part-1/Sec-2), Appendix – C. Unconfined compressive strength shall be calculated from the results of Geotechnical

Investigation Reports. Cohesion as calculated using unconsolidated untrained test with required modification of angle of internal friction will be used for working out unconfined compressive strength.

3.8.2 Pile Cap

The minimum thickness of pile cap shall be kept as 1.5 times the pile diameter. Top of the pile shall project 100mm into the pile cap.

The top of pile cap shall be kept at least 500mm below the ground level in case of urban flyovers structures or road over bridges.

Pile cap will be designed either by truss analogy or by bending theory, depending upon the spacing and number of piles in a pile group. Truss analogy may be used for pile caps with a maximum of 6 piles in a pile group. Beyond 6 piles, bending theory shall be used.

Pile cap will be provided with an offset of at least 150mm beyond the outer face of the outer piles.

3.8.3 Piers and Pier Cap

Shape of pier as far as possible shall be kept as wall type sleek pier.

The piers are to be designed for combined axial load and biaxial bending as per the provisions of IRC: 112-2020.

Pier cap is checked as either as a flexural member or as a bracket, depending upon the span / depth ratio.

In case it is a flexural member, the bending moments are checked at the face of pier support. Shear force shall be checked at a distance deff away from the face of support.

In case the pier cap acts as a bracket, the design shall conform to provisions of IS: 456 in absence of any specific provision in IRC code for bracket design.

Analysis, design and detailing will in general conform to the stipulations of relevant IRC codes and good engineering practice.

3.8.4 Superstructure

3.8.4.1 Design of PSC I-Girder and Slab (Pre-cast Girder and in-situ slab)

- The design of such type of structure is very much dependent on the construction

sequence. The structure is in iso-static condition up to the stage of casting of deck slab and diaphragm and after developing proper bond with girder, the structure behave as composite section.

- The design therefore shall be done with only the girder section being effective upto the stage of casting of deck slab and diaphragm and composite section shall be considered for all subsequent loads (i.e for SIDL and live loads).
- The deck structure will be analyzed using grillage analogy method for SIDL and Live Loads. Self weight of girder and Dead Load of slab will be applicable on girder section alone and hence the design forces for DL will be calculated separately and results superimposed. The superstructure will be idealized into a crises cross set of discrete torsion less members which are able to resist the loads applied in a plane perpendicular to the plane of assemblage, through bending and shear of the members.
- The minimum dimension of various elements shall be provided conforming to the latest IRC codes and standards. The minimum thickness of deck slab including that at tip of the cantilever shall be 200mm. The thickness of web shall not be less than 290mm. Thickness of cross girders shall not be less than the minimum web thickness of main longitudinal girder. There shall be at least three cross girders in any beam and slab type structure (i.e one at the centre and two at the ends).
- For obtaining maximum shear stress, the section at a distance equal to effective depth from the face of the support shall be checked and the shear reinforcement calculated at the section shall be continued up to the support.
- The design of deck slab supported transversely on the pre-cast girder shall be carried out assuming un-yielding support at the girder points.
- Effect of differential shrinkage and creep between pre-cast girder and in-situ slab shall be considered.
- Prestress forces and losses due to instantaneous and time dependent and extra 20%time dependent loss as specified in the code shall be considered.

3.8.4.2 Design of UHPFRC Strutted Box Girder

The design methodology of a UHPFRC Strutted box girder with a cast-in-situ deck slab using MIDAS Civil involves detailed modelling of the entire box section represent the monolithic construction. The structural cross-section includes top and bottom slabs, vertical webs, and internal diaphragms if required, with material properties such as M155

concrete for the girder and M55 for the deck slab, along with Fe 550 reinforcement. Appropriate support conditions typically fixed, pinned, or elastomeric bearings—are assigned based on span arrangement and continuity. Load definitions include self-weight (automatically considered by STAAD), superimposed dead loads (Crash barrier, wearing course), live loads as per IRC:6 (such as Class A or 70R vehicles), and prestressing forces modelled either as equivalent tendon forces or pressure loads simulating the effect of pre-tensioning or post-tensioning. Load combinations are created per IRC:6 or IRC:112 for both service and ultimate limit states. After analysis, the output from STAAD.Pro provides bending moments, shear forces, and deflections, which are used to verify sectional capacity, stress limits, and serviceability criteria. The cast-in-situ deck slab, which forms the top flange of the box section, is designed for one-way or two-way bending and shear using results from STAAD, following IRC:112 provisions. Detailing includes longitudinal and transverse reinforcement, anchorage zones for prestressing, and construction sequence considerations. This method provides flexibility for complex alignments and ensures structural continuity, durability, and performance in curved or skewed urban bridge applications.

3.9 Bearings

Bridge bearing must be designed to transmit all the loads and appropriate horizontal forces. From the material point of view, these bearings can be made from metal, rubber, metal and elastomer and even concrete. However, POT PTFE/Spherical bearings are recommended to be used on this project.

POT/PTFE Bearings

A **POT-PTFE bearing** is a type of structural bearing used in bridges and other large structures to accommodate **vertical loads**, **horizontal movements**, and **rotations** while minimizing resistance and ensuring structural stability. It combines the strength of a **POT bearing** with the low-friction properties of **PTFE (Polytetrafluoroethylene)**, making it ideal for **high-load and high-movement** urban infrastructure like flyovers, metro viaducts, and elevated corridors.

Provision of POT-PTFE Bearing shall be done as per design requirements.

The design of the POT/ PTFE bearing shall be done by the manufacturer conforming to the provisions of material as well as design parameters IRC: 83(part-III) and shall be got approved by the engineer. However, the forces, movements and rotation etc shall be provided by the designer of the project on the format given in appendix –1 of IRC:

83 (part-III). In support of quality assurance, acceptance specification given in clause 928 of IRC: 83 (part-III) shall be followed.

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CHAPTER 4. TRAFFIC SURVEYS AND ANALYSIS

4.1 GENERAL

In order to design the proposed elevated corridor, the road capacity requirements have to be ascertained. The capacity requirements in terms of carriageway widths can only be analyzed by estimating the traffic that will potentially use the proposed elevated corridors once they are constructed.

The traffic using the proposed corridor will comprise not only vehicles currently travelling along the alignment but also additional traffic attracted from other parts of the road network, owing to the corridor's higher travel speeds, reduced travel times, and direct connectivity compared to existing alternative routes. The traffic surveys conducted at following locations as per TOR are presented in **Table 4.1**.

Table 4.1: Traffic Survey Schedule

Sl. No	Station No.	Location Name	Date and Duration
Classified Traffic Volume Count			
1	TVC 01	Near Shiva Temple, West of Chord Road to Outer Ring Road via Pipeline Road	12-08-2025

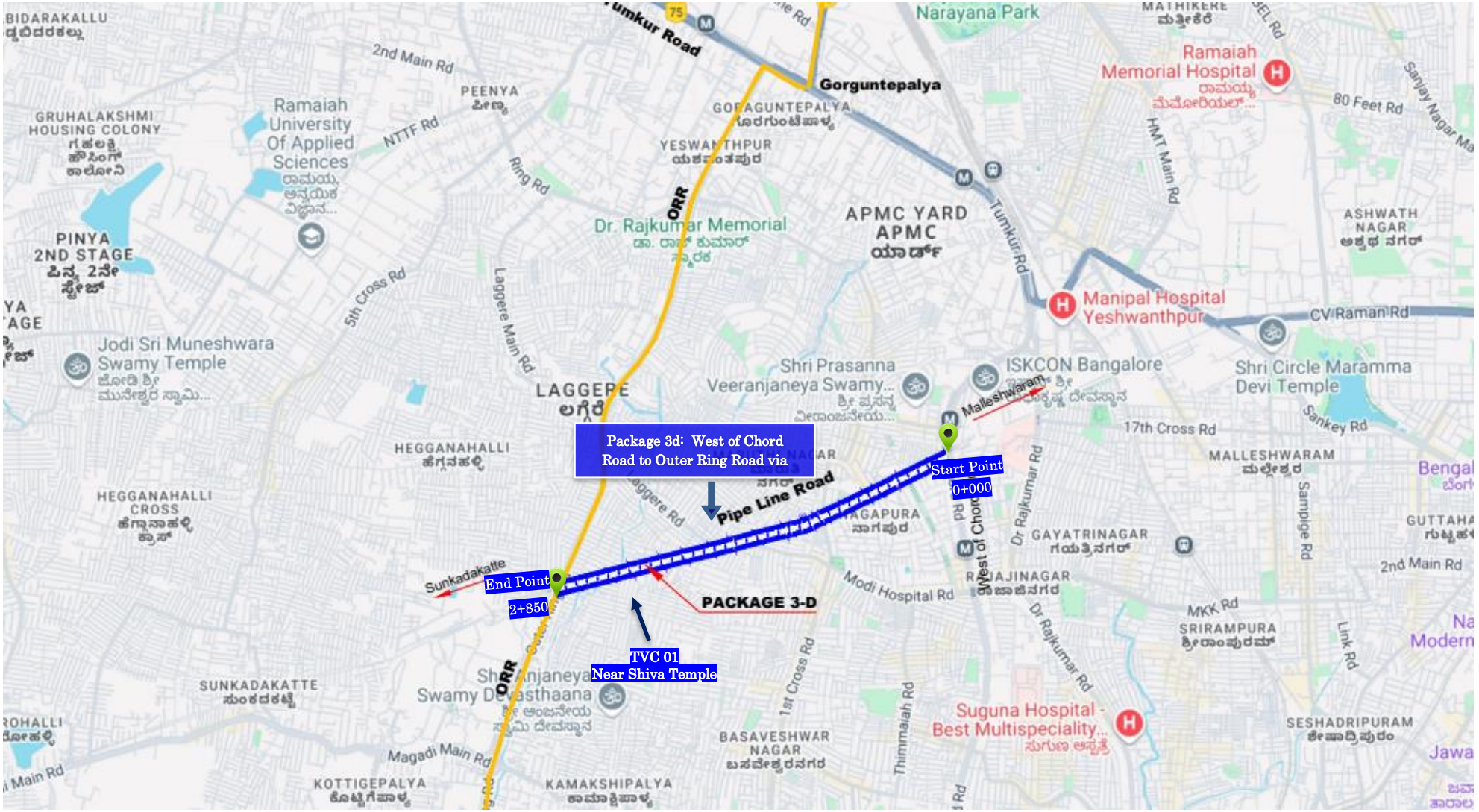

Figure 4.1 : Key Map showing Traffic Survey Locations

4.2 METHODOLOGY FOR TRAFFIC SURVEYS

Traffic Volume Count (TVC) Survey

A comprehensive 24-hour classified traffic volume survey was carried out using **high resolution video cameras** strategically installed at key locations along the proposed corridor. The objective of the survey was to capture real-time traffic flow data over an entire day, including both peak and non-peak hours. The video-based method allowed for non-intrusive, continuous monitoring of traffic conditions without disrupting normal vehicular movement. The recorded footage was subsequently reviewed and analyzed to classify vehicles into categories such as two-wheelers, cars, buses, trucks, auto-rickshaws, and others as given in below table. This approach ensured accurate enumeration and classification of all vehicle types, providing reliable data for understanding traffic patterns, vehicle mix, and hourly traffic variations. The survey formed a crucial input for assessing current traffic conditions and planning infrastructure interventions accordingly.

Table 4.2: Vehicle Classification System

Motorized Traffic		Non-Motorized Traffic
2-Wheeler		Bi-Cycle
3-Wheeler		Cycle-Rickshaw
Passenger Car		Animal Drawn Vehicle (ADV)
Utility Vehicle (Jeep, Van etc)		Hand Cart
Bus	Mini Bus	Other Non-Motorized Vehicle
	Standard Bus	
LCV	LCV – Passenger	
	LCV – Freight	
Truck	MCV - 2 Axle Rigid Chassis	
	HCV - 3 Axle Rigid Chassis	
	MAV - Semi Articulated	
	MAV - Articulated	

The classified traffic volume count surveys were carried out for one full day (continuous, direction-wise) at each of the selected survey stations. A total of three locations were identified for conducting these surveys to capture continuous, direction-wise traffic movement and vehicle classification for subsequent analysis.

The volume count data was processed and compiled using Spread Sheet software packages to get hourly and direction-wise classified traffic data. The analysis of the classified traffic volume count observed at the count locations was carried out to arrive at the following:

- Average Daily Traffic (ADT)
- Hourly variation and Peak Hour Factor (PHF)
- Directional distribution
- Traffic composition
- Annual Average Daily Traffic (AADT)

Origin-Destination Survey

Origin Destination Survey aims at Establishing

- Origin and Destination of the trip
- Trip length
- Trip purpose and occupancy for car users
- Type of commodity and load carried for goods vehicles

The results of these surveys form useful inputs for establishing travel characteristics, identifying project road influence area, estimating potential divertible traffic on various alternative routes by different OD pairs and working out the actual distance travelled on the Project Road by various traffic streams.

Although multiple roads currently exist in the proposed project influence area, their at-grade operation through highly developed urban stretches leads to significant travel delays at junctions, frequent stoppages, and poor reliability. Along the West of Chord Road–Outer Ring Road link via Pipeline Road, all of which are presently operating under saturated traffic conditions.

While alternate public transport such as the metro exists in Bengaluru, no direct or parallel metro connectivity is available along these corridors. The closest operational metro alignments do not provide seamless end-to-end connectivity for commuters travelling towards the airport influence zone, northern Bengaluru, or east–west arterial sectors, thereby making surface transport indispensable. In contrast, the proposed elevated corridors provide signal-free, access-controlled movement, bypassing bottlenecks and ensuring substantial reductions in travel

time and vehicle operating costs.

Given the strategic alignment, direct connectivity to growth areas, integration with existing and proposed elevated corridors, and the inherent travel time savings, a high share of through-traffic is expected to naturally shift to these facilities. This strong likelihood of demand capture, supported by observed congestion levels and corridor utility, inherently validates the project's necessity. Accordingly, a full-scale Origin–Destination (O-D) survey is not warranted, as the traffic justification is self-evident from existing ground conditions and travel demand patterns.

4.3 DATA ANALYSIS

The survey data and pertinent information collected from various traffic surveys discussed in preceding section of this chapter were analyzed to obtain the various traffic characteristics on the study corridor. Brief discussions on the findings are presented hereunder.

4.3.1 Traffic Volume Count Survey

Traffic volume count data collected at different locations has been analyzed to arrive at average daily traffic (ADT), hourly variation and composition. ADT in terms of total vehicles and passenger car units (PCU) are worked out. The PCU conversion factors adopted for the present study are given in **Table 4.3** and are taken from "IRC 106-1990: Guidelines for Capacity of Urban Roads in Plain Areas".

Table 4.3: Adopted PCU Values

Type	Mode	Equivalent PCU Factors Percentage composition of Vehicle type in traffic stream	
		5%	10% and above
Passenger Vehicles	Two-Wheeler	0.5	0.75
	Three-Wheeler	1.2	2
	Car/Jeep/Van/Taxi	1	1
	Mini Bus/ Tempo	1.4	2
	Standard Bus	2.2	3.7
Freight Vehicles	Mini LCV	1.4	2
	LCV	1.4	2
	2 / 3-Axle	2.2	3.7
	Multi Axle	2.2	3.7
	Agriculture Tractor	4	5

Type	Mode	Equivalent PCU Factors Percentage composition of Vehicle type in traffic stream	
		5%	10% and above
	Agriculture Tractor Trailer	4	5
Slow Moving Vehicles	Animal Drawn	1.5	2
	Hand Carts	2	3
	Cycle	0.4	0.5
	Cycle Rickshaw	1.5	2.0

Average Daily Traffic (ADT)

Hourly traffic data collected using high-resolution video cameras over a continuous 24-hour period at each count station was aggregated to obtain the daily traffic volumes. These volumes were then used directly for analysis at the respective survey locations.

Observations (Traffic Volume Count Survey)

The following observations are made from each traffic volume count survey.

4.3.1.1 Traffic Characteristics @ TVC 01 (Near Shiva Temple)

- A total of about 43787 vehicles (42332 PCU's) pass at this point in both directions per day.
- Goods vehicles account for 3.22 % and passenger vehicles account for 96.78 % of the total traffic. Non-motorized traffic constitutes about 0.00 % of total vehicles.
- Among the passenger vehicles two wheelers and cars are the dominant ones constituting about 52.73 % and 36.36 %. Whereas auto and buses are at 6.97 % and 0.72 % respectively.
- Goods traffic consists of LCVs (2.29 %), HCVs (0.78 %), MAVs (0.15 %) and Agricultural Tractors (0.00%).
- The peak hour traffic is 3407 PCUs, which is 8.05% of ADT.

There is directional balance in terms of traffic plying in the two directions (41:59). **Figure 4.2** and **Figure 4.3** shows Traffic Composition and hourly variation of traffic at location.

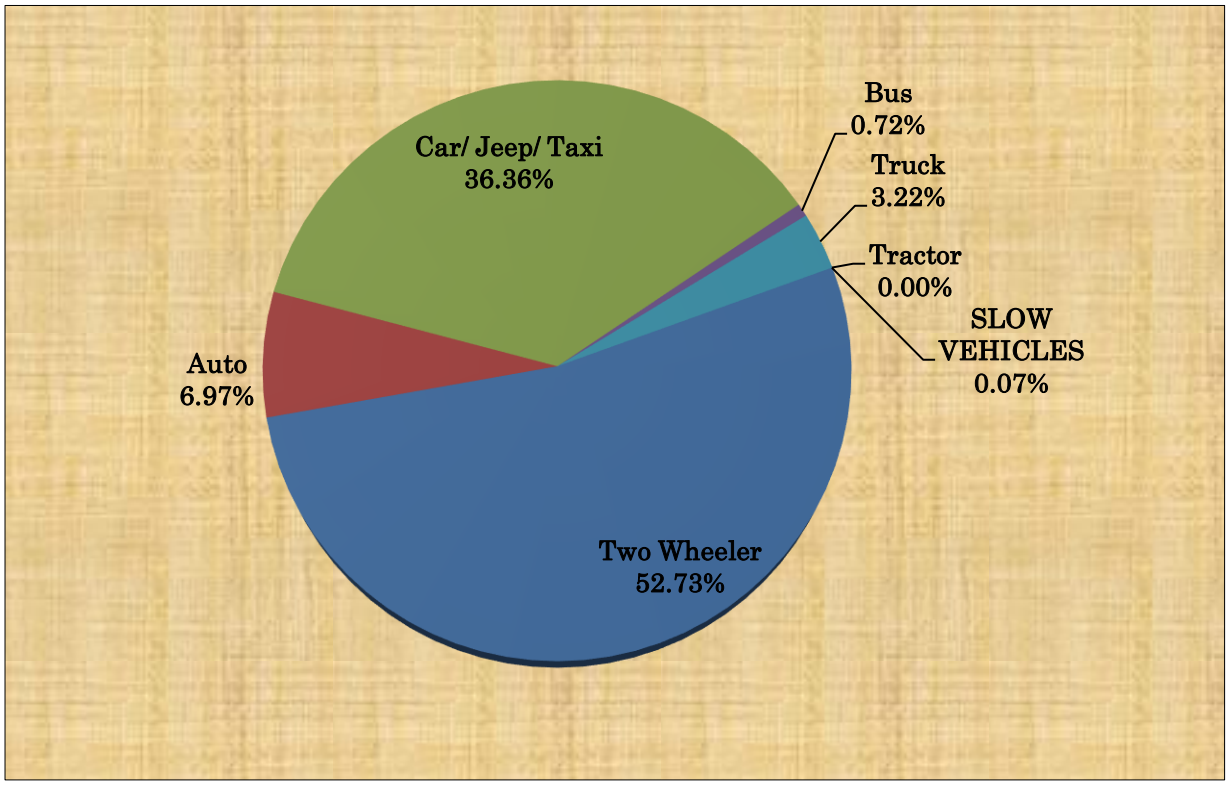

Figure 4.2 : Traffic Composition at TVC 01 (Near Shiva Temple)

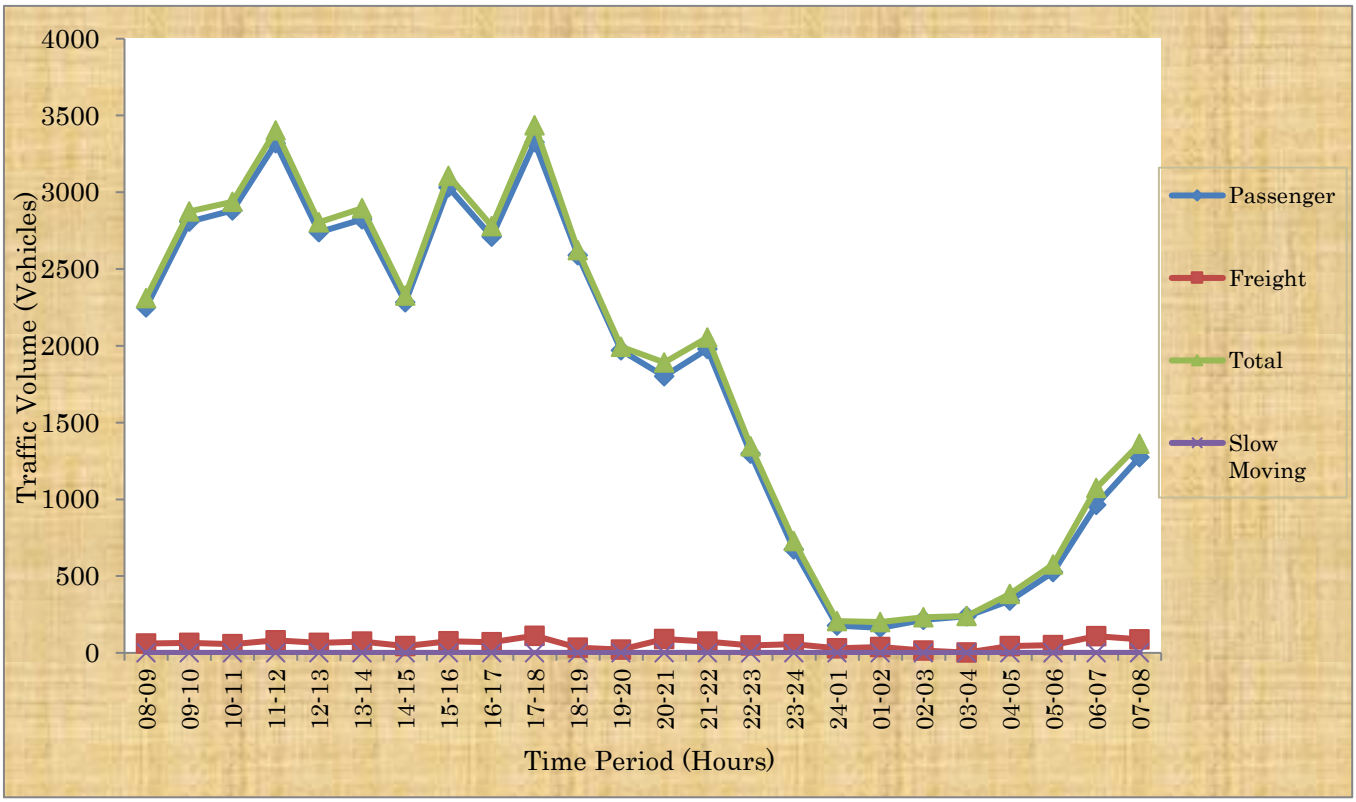

Figure 4.3 : Hourly Traffic at TVC 01 (Near Shiva Temple)

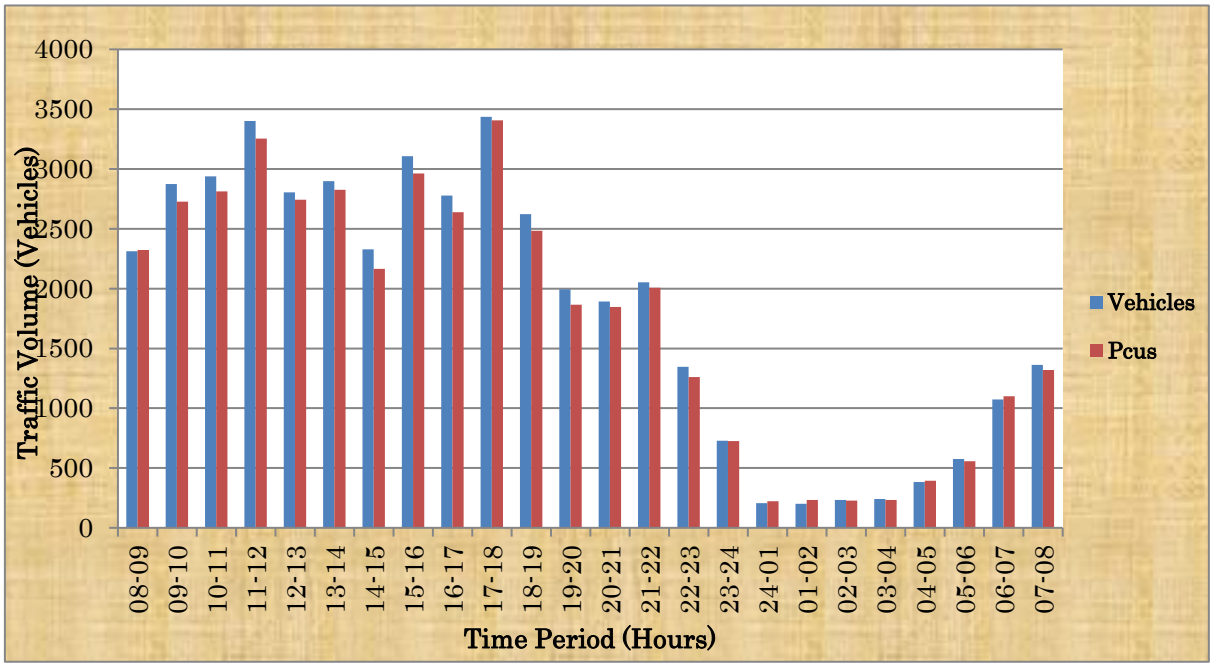

Figure 4.4 : Hourly Variation at TVC 01 Near Shiva Temple

A summary of direction-wise daily traffic along with the Average Daily Traffic is presented in **Table 4.4** below.

Table 4.4: Average Daily Traffic (ADT) for TVC 01 Near Shiva Temple

Type	Mode	West Chord Road to Outer Ring Road	Outer Ring Road to West Chord Road	Both Directions
Passenger	Two-Wheeler	9619	13471	23090
	Auto Rikshaw	1336	1715	3051
	Car/ Jeep / Taxi	6196	9727	15923
	Mini Bus	0	0	0
	Std Bus	80	235	315
Goods	Mini LCV	0	0	0
	LCV	324	678	1002
	2 Axle	104	105	209
	3 Axle	66	66	132
	MAV	32	33	65
Tractor	Agr. Tractor	0	0	0
	Agr. Tractor Trailer	0	0	0
Slow MovingVehicle		0	0	0
Total Vehicles		**17757**	**26030**	**43787**
Total PCUs		**17156**	**25175**	**42332**

Annual Average Daily Traffic

The traffic plying on any road generally varies over the different periods of the year depending on the cycle of different socio-economic activities in the region through which it passes. Therefore, in order to have more realistic estimate of the traffic on the project road, it is required to assess seasonal variation in traffic over a year to estimate Annual Average Daily Traffic (AADT). The ADT observed during the survey duration is multiplied by a Seasonal Correction Factor (SCF) to derive AADT.

The seasonal correction factor is generally derived from secondary data sources such as past month-wise traffic data on the project road, monthly toll revenues from existing tolled highways in the immediate influence area, sales of fuel at different filling stations along the project road.

No seasonal correction factor for the traffic has been considered as this city traffic is not susceptible to seasonal variation. For the present study, the SCF is considered as 1.00 for both HSD and MS vehicles as there will be only minimal variation in SCF for Urban area. Hence AADT is adopted same as ADT, which is represented in earlier paragraphs.

4.3.2 Origin – Destination Survey

Origin Destination Survey aims at Establishing

- Origin and Destination of the trip
- Trip length
- Trip purpose and occupancy for car users
- Type of commodity and load carried for goods vehicles

The results of these surveys form useful inputs for establishing travel characteristics, identifying project road influence area, estimating potential divertible traffic on various alternative routes by different OD pairs and working out the actual distance travelled on the Project Road by various traffic streams.

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metro alignments do not provide seamless end-to-end connectivity for commuters, thereby making surface transport indispensable. In contrast, the proposed elevated corridors provide signal-free, access-controlled movement, bypassing bottlenecks and ensuring substantial reductions in travel time and vehicle operating costs.

Given the strategic alignment, direct connectivity to growth areas, integration with existing and proposed elevated corridor, and the inherent travel time savings, a high share of through-traffic is expected to naturally shift to these facilities. This strong likelihood of demand capture, supported by observed congestion levels and corridor utility, inherently validates the project's necessity. Accordingly, a full-scale Origin–Destination (O-D) survey is not warranted, as the traffic justification is self-evident from existing ground conditions and travel demand patterns.

4.3.3 Traffic Growth Rate

For proposed elevated corridors, a conservative minimum annual traffic growth rate of 5% has been adopted for all vehicle categories. Even though the city has seen very high growth rates in the past it is expected that the personal vehicle growth might come down due to expansion of Metro network, addition of more buses to BMTC, and proposed Sub urban rail network. Applying this growth rate provides a prudent basis for estimating the design traffic for both the flyover and the elevated corridor, ensuring that the pavement and associated infrastructure are capable of accommodating current and projected traffic volumes over the respective design lives of the two components. The cardinal years projected traffic for each traffic survey locations are given below

Table 4.5: Cardinal Years Projected Traffic for TVC 01

Projected Traffic Near Shiva Temple																		
Years	Motorized Vehicles													Non-Motorized Vehicles			Total	
	Two-Wheeler	Auto Rickshaw	Car/ Jeep / Taxi	Mini LCV	Mini Bus	Std Bus 2 Axle	Std Bus 3 Axle	Trucks				Tractor	Tractor-trailers	Animal Drawn	Hand Carts	Cycle	Vehicles	PCUS
								LCV	2-Axle	3-Axle	MAV							
2025	23090	3051	15923	0	0	315	0	1002	209	132	65	0	0	0	0	0	**43787**	**42332**
2026	24245	3204	16719	0	0	331	0	1052	219	139	68	0	0	0	0	0	**45976**	**44448**
2027	25457	3364	17555	0	0	347	0	1105	230	145	72	0	0	0	0	0	**48275**	**46670**
2028	**26730**	**3532**	**18433**	**0**	**0**	**365**	**0**	**1160**	**242**	**153**	**75**	**0**	**0**	**0**	**0**	**0**	**50689**	**49004**
2029	28066	3709	19355	0	0	383	0	1218	254	160	79	0	0	0	0	0	**53223**	**51454**
2030	29469	3894	20322	0	0	402	0	1279	267	168	83	0	0	0	0	0	**55885**	**54027**
2031	30943	4089	21338	0	0	422	0	1343	280	177	87	0	0	0	0	0	**58679**	**56728**
2032	32490	4293	22405	0	0	443	0	1410	294	186	92	0	0	0	0	0	**61613**	**59565**
2033	**34114**	**4508**	**23526**	**0**	**0**	**465**	**0**	**1480**	**309**	**195**	**96**	**0**	**0**	**0**	**0**	**0**	**64693**	**62543**
2034	35820	4733	24702	0	0	489	0	1554	324	205	101	0	0	0	0	0	**67928**	**65670**
2035	37611	4970	25937	0	0	513	0	1632	340	215	106	0	0	0	0	0	**71324**	**68954**
2036	39492	5218	27234	0	0	539	0	1714	357	226	111	0	0	0	0	0	**74891**	**72401**
2037	41466	5479	28595	0	0	566	0	1799	375	237	117	0	0	0	0	0	**78635**	**76021**
2038	**43540**	**5753**	**30025**	**0**	**0**	**594**	**0**	**1889**	**394**	**249**	**123**	**0**	**0**	**0**	**0**	**0**	**82567**	**79822**

Projected Traffic Near Shiva Temple																		
Years	Motorized Vehicles													Non-Motorized Vehicles			Total	
	Two-Wheeler	Auto Rickshaw	Car/ Jeep / Taxi	Mini LCV	Mini Bus	Std Bus 2 Axle	Std Bus 3 Axle	Trucks				Tractor	Tractor-trailers	Animal Drawn	Hand Carts	Cycle	Vehicles	PCUS
								LCV	2-Axle	3-Axle	MAV							
2039	45717	6041	31526	0	0	624	0	1984	414	261	129	0	0	0	0	0	**86695**	**83813**
2040	48002	6343	33103	0	0	655	0	2083	434	274	135	0	0	0	0	0	**91030**	**88004**
2041	50403	6660	34758	0	0	688	0	2187	456	288	142	0	0	0	0	0	**95582**	**92404**
2042	52923	6993	36496	0	0	722	0	2297	479	302	149	0	0	0	0	0	**100361**	**97025**
2043	**55569**	**7343**	**38321**	**0**	**0**	**758**	**0**	**2411**	**503**	**318**	**157**	**0**	**0**	**0**	**0**	**0**	**105379**	**101876**
2044	58347	7710	40237	0	0	796	0	2532	528	333	164	0	0	0	0	0	**110648**	**106970**
2045	61265	8095	42248	0	0	836	0	2659	554	350	173	0	0	0	0	0	**116180**	**112318**
2046	64328	8500	44361	0	0	878	0	2792	582	368	181	0	0	0	0	0	**121989**	**117934**
2047	67544	8925	46579	0	0	921	0	2931	611	386	190	0	0	0	0	0	**128088**	**123831**
2048	**70921**	**9371**	**48908**	**0**	**0**	**968**	**0**	**3078**	**642**	**405**	**200**	**0**	**0**	**0**	**0**	**0**	**134493**	**130022**

Table 4.6: Cardinal Years Projected Traffic

Cardinal Year	Cardinal Years Traffic, (PCU)
	TVC 01
Growth Rate, %	5%
2025	42,332
2028	53,904
2033	72,237
2038	87,805
2043	1,12,063
2048	1,43,024

Method & Inputs

Facility type: Urban divided/proposed elevated arterial (access-controlled where elevated).

Lane configuration considered for capacity check: 6-lane divided (three lanes, two-way).

Design Capacity (two-way, planning value): 3,600 PCU/h (≈ 900 PCU/h/lane × 4 lanes).

Peak-hour demand: Peak Hour % of ADT at each TVC.

V/C ratio: V/C = Peak-Hour Volume (PCU/h) / Design Capacity (PCU/h).

LOS (indicative, planning thresholds):

Table 4.7: Level of Service, Criteria as per IRC 106 1990

LOS	V/C Range	Condition Description (Based on IRC 106–1990, Table 9 and Table 8 criteria for urban roads)
A	≤ 0.35	Free flow — speeds ≈ 90% of free-flow, minimal driver interaction.
B	0.36 – 0.54	Stable flow — speeds ~70% of free-flow, some restrictions.
C	0.55 – 0.77	Stable, but individual speed/ maneuvering affected.
D	0.78 – 0.93	Approaching unstable — high density, comfort declining.
E	0.94 – 1.00	At or near capacity — speeds ~⅓ of free-flow, unstable.
F	> 1.00	Over-capacity — breakdown/forced flow, queuing.

Growth: Most-likely projection already incorporated in the ADT/PCU.

Notes: Planning capacities and service thresholds are aligned with common Indian practice based on IRC guidance for urban roads/elevated corridors (IRC 64/92/106 and related urban capacity references).

4.3.4.1 Capacity Analysis by TVC

Table 4.8: Capacity Analysis at TVC 01

Year	ADT (PCU/day)	Peak-hour % of ADT	Peak-hour Volume (PCU/h)	Design Capacity (PCU/h)	V/C	LOS
2025	42,332	8.05%	3408	3,600	0.95	E
2028	49,004	8.05%	3945	3,600	1.10	F
2033	62,543	8.05%	5035	3,600	1.40	F
2038	79,822	8.05%	6426	3,600	1.78	F
2043	1,01,876	8.05%	8201	3,600	2.28	F
2048	1,30,022	8.05%	10467	3,600	2.91	F

Inference (TVC-01): At threshold in 2025 (V/C ≈ 0.95). With growth, elevated operation is required; near-term auxiliary lanes at ramps/weaving sections are recommended.

4.3.4.2 Capacity Augmentation & DPR Recommendations

Table 4.9: Capacity Augmentation & DPR Recommendations

TVC Location	Existing / Proposed Configuration	Threshold Year (V/C>1.0)	DPR Recommendation
TVC-01	Elevated Corridor 2×2 lanes (7.5 m CW + 1.5 m PS/side)	2025	Immediate elevated; near-term auxiliary / acceleration deceleration lanes at merges / diverges; ramp spacing and weaving control per IRC. Stage for future 3 lanes/dir at hotspots.

Operational Measures (all locations): adaptive signal control on surface network, queue detectors on ramps, incident management & breakdown bays on the elevated, HCM-style weaving checks, and heavy-vehicle peak restrictions where feasible.

4.4 DISCUSSIONS AND CONCLUSIONS

The capacity assessment carried out at classified TVCs along the alignment TVC-01 (near Elements Mall), shows that peak-hour volumes are already at or very close to the practical planning capacity of a 4-lane urban arterial elevated facility (≈3,600 PCU/h two-way) in the opening year (2025). Computed V/C ratios for 2025 are approximately 0.95 (TVC-01), deteriorating rapidly under the conservative 5% annual traffic growth assumption. By the near-term horizon all three TVCs are projected to operate at LOS-E/F, with peak-period queuing and breakdown expected at critical merge/weave locations.

The corridor traverses densely built urban sectors with frequent major and minor junctions and short inter-junction spacings (varied from a few hundred metres to a few kilometres). Isolated grade separators or local capacity treatments at single junctions are unlikely to provide lasting relief because they transfer congestion downstream and typically require substantially larger ROW and staging impacts in a constrained urban setting. By contrast, a continuous, access-controlled elevated corridor provides through-capacity by segregating long-distance and through traffic from local at-grade movements, preserves operational efficiency on the surface network, and minimizes repeated ROW widening and property impacts.

Accordingly, the DPR recommends implementation of an access-controlled elevated corridor as the preferred capacity-augmentation strategy. Key design and operational measures to be included are: provision of auxiliary acceleration/deceleration lanes at ramp merges/diverges, optimized ramp spacing and ramp geometry to reduce weaving, shoulders for incident management, ITS/ITMS (CCTV, VMS, ramp-metering capability and incident detection), protected utility ducts to avoid frequent road reopening, and structural provision for staged future widening (allowing conversion to 3 lanes/dir or addition of auxiliary lanes at forecasted hotspots). These integrated measures are necessary to meet the design-year demand while maintaining acceptable service levels and safety in the highly constrained urban corridor.

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CHAPTER 5. IMPROVEMENT PROPOSALS

5.1 GENERAL

The primary objective of the Elevated Corridor Project in Bengaluru is to develop an elevated road network aimed at significantly decongesting the city's surface roads, enhancing traffic flow, reducing travel time, and improving overall connectivity across key corridors within the metropolitan area.

This objective aligns with the broader goal of modernizing Bengaluru's urban infrastructure to meet the demands of rapid urbanization, increasing vehicular density, and the growing need for efficient intra-city mobility. By providing grade-separated corridors for vehicular movement, the project seeks to:

- Divert through-traffic from congested surface roads to elevated routes.
- Improve accessibility between major residential, commercial, and industrial zones.
- Reduce bottlenecks and travel delays during peak hours.
- Facilitate faster movement of goods and public transport.
- Support long-term urban and economic development through infrastructure enhancement.

The project is envisioned as a critical intervention in addressing Bengaluru's chronic traffic issues and will be integrated with other ongoing transport and infrastructure initiatives

5.2 PROJECT ALIGNMENT

Project comprises the preparation of a Detailed Project Report (DPR) for elevated corridor proposed to strengthen the road network, easing traffic congestion and improve mobility in the northern and eastern parts of Bengaluru. Together, these corridors aim to provide seamless connectivity between major arterial roads and peripheral growth areas, thereby reducing congestion on existing roadways.

The proposed project Elevated Corridor from **West of Chord Road to Outer Ring Road Corridor via Pipeline Road (2.20 km):** This corridor is planned from West of Chord Road (Ch. 0+000) to Outer Ring Road (Ch. 2+850), passing through Mahalakshipuram, Nagapura, and Basaveshwaranagar. However, since a **Grade Separator between Ch. 2+200 and Ch. 2+850 is already under construction**, the elevated corridor improvements will be limited to the section between **Ch. 0+000 and Ch. 2+200**. This intervention is

expected to improve east–west connectivity and ease congestion along the adjoining internal road networks.

Accordingly, the Summary of Length of Proposed Corridor is given below

Sl No	Name	From	To	Length, m
1	Preparation of Detailed Project Report (DPR) for Construction of Elevated from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout)	0+000	2+200	2200
Total Improvement Length (Excluding Ramps & Loops), m				**2200**

The details of total length for the development is given in the below table.

Table 5.1 : Summary of Proposed Improvements along the Project Corridor

Sl No.	Description	Total Length in m
1	Length of Main Carriageway	1580
2	Length of Roundabout (Junctions)	
3	Length of Split CW Section	
4	Length of Ramps Section (MCW)	400
5	Length of Curved Section	
6	Length of Taper section	
7	Length of Down ramp	
8	Length of up ramp	
9	Length of Viaduct ramp (Up and Down)	
10	Length of Up & Down ramp	
11	Length of Connecting Road	
Total		**1980**

5.3 IMPROVEMENT PROPOSALS

Improvement works are proposed for the following stretches and the summary of the improvement lengths is represented below.

Table 5.2 : Proposed Improvements along the Project Corridor

Sl.	Parameter	West of Chord Road to Outer Ring Road
1	Length of Main Carriageway	1580
2	Length of Roundabout (Junctions)	
3	Length of Split CW Section	
4	Length of Ramps Section (MCW)	400
5	Length of Curved Section	
6	Length of Taper section	
7	Length of Down ramp	
8	Length of up ramp	
9	Length of Viaduct ramp (Up and Down)	
10	Length of Up & Down ramp	
11	Length of Connecting Road	
	Total length of Improvement-Elevated	**1980**
	Total length of Improvement-At_grade	**2100**

The project corridor is studied with respect to the existing features on the project roads viz No of lanes, carriageway details, Drains and CDs, Footpaths, Medians, Junctions, sign Boards, traffic delays and other traffic safety appurtenances along the project corridor. Accordingly, Improvement Proposals for the corridor are listed and briefed below.

5.3.1 Elevated Improvement Proposals

5.3.1.1 Choice of Structural Material:

The choice of Structure material Such as Conventional concrete/Ultra high-performance concrete is a major decision to be taken for long elevated corridor for bridge engineers. Selection of type of structural material and arrangement are governed by many factors such as availability of material, space for construction, Duration of project, construction technology, Cost of project, feasibility of construction and social and environmental impact etc.

However, only four factors pertinent to bridges need concern us:

I. Relative economy,
II. Speed of erection,
III. Aesthetic considerations, and

IV. Corrosion / maintenance.

5.3.1.2 Ultra-High Performance Fiber Reinforced Concrete (UHPFRC)

- It eliminates aggregate; mainly uses steel fiber as reinforcement.
- UHPFRC is efficient for structure of long span bridges with thin sections.
- With usable structural ultimate tensile strength will be more than 8MPa and Ultimate flexural strength is more than 30Mpa
- Concrete cover is not compulsory to be maintained.
- It is highly flowable and mouldable.
- Honeycomb formation is almost impossible.
- It has high compressive strength.
- It has low carbon footprint
- Longer service life and more durable
- Dead weight of Structure will be less compared to conventional concrete.

Table 5.3 : Applications of UHPFRC

Aspect	UHPFRC (Ultra-High-Performance Fiber-Reinforced Concrete)
Span Length	Capable of longer spans with thinner sections
Landscape Integration	Slim profiles; minimal visual and physical intrusion in urban context
Environmental Impact	Lower over lifecycle; reduced materials, fewer repairs, longer life
Structural Performance	Superior; high compressive & tensile strength, excellent durability
Constructability	Precast slim sections allow faster, modular, and more precise construction
Maintenance	Very low; tight micro-cracks and dense matrix resist degradation
Construction Period	Shorter; faster erection, fewer joints, and prefabrication-friendly
Cost	Higher initial cost, but lower lifecycle and maintenance cost

5.3.1.3 Structural Arrangement

The project corridor comprises of various spans of structures. The proposed corridor is for urban area with many crossroads of various widths and require different

obligatory spans with faster mode of construction. The total deck width of elevated road main alignment is 19. 61m.Also,5.5m and 10.61m Deck Width for Up ramp and Down ramp. Deck width of Split flyover and Double Decker is 10m for each carriageway. The configuration of deck is detailed as below,

Table 5.4 : Deck Slab Configuration

SL No.	No. of Lanes	CB (m)	SH (m)	CW (m)	SHY (m)	Median (m)	SHY (m)	CW (m)	SH (m)	CB (m)	Total Width	Remarks
1.	Four Lane	0.5	1.5	7.0	0.5	0.61	0.5	7.0	1.5	0.5	19.61	Main Alignment

CB: Crash barrier, SHY: Kerb Shyness, CW: Carriageway, SH: Shoulder

The structural configuration comprises of various arrangements with divided decks, portal piers, pile foundations etc. The arrangement of substructure depends on the availability of space at grade. As the corridor is in urban area care has been taken to provide best suitable configuration such that minimum hindrances to the at grade traffic. Each location is studied in detail with respect to detail topographic survey and site condition before providing the pier locations and structural systems. Details Schedule of structural Proposal is presented in tables below. The Details of each cross section has been presented in Volume-III-Drawings.

Span configuration and type of superstructure used in this project is given in table below.

Table 5.5 : Span configuration and type of superstructure

SL No.	Span Configuration	Type of Superstructure	Deck Width
1.	30.0	Precast PSC-I-Girder	19.61m
2	50.0	UHPFRC Strutted Box	19.61m

5.3.1.4 Superstructure:

Prestressed Concrete (PSC) I-girders are widely used in urban infrastructure projects due to their efficiency, strength, and suitability for precast construction. Urban areas often face space constraints, and PSC I-girders, being precast, can be manufactured off-site and installed quickly, reducing on-site congestion and construction time. Their ability to bear heavy loads over long spans makes them ideal for flyovers, metro viaducts, and elevated roads, while their durability and resistance to cracking minimize

maintenance needs—crucial in areas with limited access for repairs. Additionally, PSC I-girders can be designed to integrate with urban aesthetics or meet architectural requirements, making them a practical and visually adaptable solution for modern city infrastructure.

Ultra-High-Performance Fiber-Reinforced Concrete (UHPFRC) strutted box structures are innovative bridge solutions well-suited for urban infrastructure, addressing challenges like limited space, aesthetic integration, and the need for rapid construction. Featuring single or multi-cell box sections with integrated struts or diaphragms, these systems offer enhanced torsional stiffness, efficient load distribution, and structural stability. Leveraging the exceptional properties of UHPFRC-such as compressive strengths exceeding 150 MPa and outstanding durability-these structures allow for thinner walls, reduced self-weight, and longer spans, minimizing the need for intermediate supports and maximizing usable space below the deck. Their precast, modular nature ensures quality control, rapid onsite assembly using cranes or launching girders, and reduced traffic disruption-critical in dense urban settings. Commonly used in metro viaducts, flyovers, and grade separators, UHPFRC strutted boxes combine structural efficiency, aesthetic appeal, and long-term sustainability, making them a preferred choice for modern urban bridge construction.

Table 5.6 : Comparative Statement of Super Structure

Feature / Type	PSC I-Girder	UHPFRC Strutted Box Girder
Cross-section Shape	I-shaped	Hollow box
Construction Method	Precast	Precast segmental
Span Length	Short to Moderate spans	Long spans, fewer supports
Torsional Rigidity	Low (not suitable for curves)	High (ideal for curves/skewed alignments)
Typical Applications	Viaducts in Straight portion	Longer Span Viaducts in Straight portion
Aesthetic Appeal	Can be customized but open web visible	Thinner sections,Clean, enclosed appearance
Noise & Vibration	Moderate	Good noise & vibration control

Feature / Type	PSC I-Girder	UHPFRC Strutted Box Girder
Ground Impact (Piers)	Moderate number of piers	Few piers (designed for longer spans)
Construction Speed	Fast (precast, quick erection)	Very fast (precast, minimal on-site work)
Maintenance	Durable but more joints	Low maintenance (monolithic structure)
Flexibility on Site	Less flexible (standard spans, straight)	Highly flexible

5.3.1.5 Structural Typical Cross Section for Main Corridor

The Span arrangement of (50m UHPFRC Shuttered box) for Project Corridor from West of Chord Road to Outer Ring Road via Pipeline Road is shown in the table below.

Table 5.7 : Structural Typical Cross Section- Project Corridor

SL No	Chainages	Proposed Pier number	Span Configuration	Remark
1	0+310	AP1		Portal Pier
2	0+340	P2	30	Portal Pier
3	0+370	P3	50	Portal Pier
4	0+420	P4	30	Portal Pier
5	0+470	P5	50	Portal Pier
6	0+520	P6	50	Portal Pier
7	0+570	P7	50	Portal Pier
8	0+620	P8	50	Portal Pier
9	0+670	P9	50	Portal Pier
10	0+720	P10	50	Portal Pier
11	0+770	P11	50	Portal Pier
12	0+820	P12	50	Portal Pier
13	0+870	P13	50	Portal Pier
14	0+920	P14	50	Portal Pier
15	0+970	P15	50	Portal Pier
16	1+020	P16	50	Portal Pier
17	1+070	P17	50	Portal Pier
18	1+120	P18	50	Portal Pier
19	1+170	P19	50	Portal Pier
20	1+200	P20	30	Portal Pier

SL No	Chainages	Proposed Pier number	Span Configuration	Remark
21	1+250	P21	50	Portal Pier
22	1+300	P22	50	Portal Pier
23	1+350	P23	50	Portal Pier
24	1+400	P24	50	Portal Pier
25	1+450	P25	50	Portal Pier
26	1+500	P26	50	Portal Pier
27	1+550	P27	50	Portal Pier
28	1+580	P28	30	Portal Pier
29	1+630	P29	50	Portal Pier
30	1+680	P30	50	Portal Pier
31	1+730	P31	50	Portal Pier
32	1+780	P32	50	Portal Pier
33	1+830	P33	50	Portal Pier
34	1+860	P34	30	Portal Pier
35	1+890	P35	30	Portal Pier

5.3.1.6 Structural Typical Cross Section for Up & Down Ramps

The Span for Up and Down Ramps of Project Corridor are shown in the table below.

Table 5.8 : Structural Typical Cross Section of Up/Down Ramps

SL No	Chainage	Proposed Pier number	Span Configuration	Remark
NIL				

5.3.1.7 Structural Analysis/ Design Methodology

Structural Analysis shall be clearly identified and explained for evolving a comprehensive design methodology, which covers all aspects of design for various parts of the structures (viz. superstructure, substructure, foundations & bearings). The design standards and specification has been presented in Chapter-4 of Volume -1 main report.

5.3.2 At Grade Improvement Proposals

5.3.2.1 Main Carriageway Improvements

The improvement of the at grade carriageway is essential for ensuring smoother & safer travel of local traffic. The main objective of improvement is to improve ride quality, reduce road maintenance efforts and ensure safety for all road users.

Case i. where existing carriageway is having Flexible Pavement: Main Carriageway improvement proposal includes Milling of existing bituminous surface, and providing White Topping in order to achieve better riding, visibility and significantly reducing maintenance cost. The proposal also includes providing proper Road Markings and road furniture's.

Case ii. where existing carriageway is having White Topping / Rigid Pavement: Main Carriageway improvement proposal includes reconstruction of damaged portion of the carriageway with conventional rigid pavement from subbase, in order to achieve uniform surface throughout the carriageway width, better riding comfort, and visibility. The proposal also includes providing proper Road Markings and road furniture's

5.3.2.2 Service Road Improvements

Service roads play a crucial role in supporting main carriageways by providing access to adjacent properties and reducing congestion on the main road. This proposal focuses on upgrading service roads to improve accessibility, safety, and overall traffic efficiency. The main objective of improvement is to enhance accessibility for local traffic and businesses,

Case i. at existing service roads: Service Road improvements proposal includes Milling of existing bituminous surface, and providing overlay with Stone Matrix Asphalt ensuring longeivity of the Pavement surface with minimal maintenance unlike other wearing courses. The proposal also includes providing proper Road Markings and road furniture.

Case ii. at proposed new construction of service roads: Service Road improvements proposal includes construction of new service roads to enhance accessibility for local traffic to residential and commercial establishments in the reach. These roads are designed for 10 msa traffic. Flexible Pavement with SMA as wearing course, and Granular base and Subbase combination is adopted to ensure longeivity of the Pavement surface with minimal maintenance. The proposal also includes providing proper Road Markings and road furniture.

5.3.3 Approach Ramps

Approach ramps are provided at start and end points of Elevated corridor and are provided for major cross roads, where significant traffic enters and exits the elevated corridor enroute. These Approach ramps play a crucial role in providing access to the

elevated corridors for the traffic moving enroute. This proposal focuses on improving accessibility, safety, and overall traffic efficiency.

The proposal includes construction of new roads with solid ramps supported by RE wall construction These roads are designed for 20 msa traffic. Flexible Pavement with SMA as wearing course, and Granular base and Subbase combination is adopted to ensure longeivity of the Pavement surface with minimal maintenance. The proposal also includes providing proper Road Markings and road furniture.

Road-3d Approach Solid Ramp			
Sl No	**From**	**To**	**Length in m**
1	120	310	190
2	1890	2100	210

5.3.4 Footpath and Kerbs

Well-designed footpaths and kerbs are essential for pedestrian safety, accessibility and urban aesthetics. This proposal focuses on upgrading pedestrian infrastructure to ensure smooth mobility, safety, and durability in urban areas. Footpath improvement reduces pedestrian-vehicle conflicts and provides Walk-friendly streets for all users, including elderly and disabled individuals. Footpath improvement proposal includes removal of damaged and nonfunctional paver blocks, kerb stones, etc and replacement with the new ones. The footpath paving patterns will include laying of dressed Granite stone slabs in combination with paver blocks improving longevity and aesthetics of the Footpath.

Footpath improvement proposal comprises, provision of underground utility ducts of HDPE pipes aided with Inspection chambers at suitable interval to facilitate operation and maintenance of the service lines provided. In addition, where space is available the proposal also includes Green Hedging provision along the footpath to enhance aesthetics.

5.3.5 Median

Medians play a crucial role in road safety by preventing accidents, controlling vehicle movement, and enhancing traffic discipline. This proposal focuses on upgrading these elements to improve road safety, reduce accidents, and enhance urban aesthetics. Provide pedestrian safety and controlled crossing points. The provision for Median construction are as shown in the Cross Section Drawings.

5.3.6 Drainage Improvement and Structural Works

Effective Road drainage is essential for maintaining road infrastructure, preventing waterlogging and ensuring safe traffic movement. This proposal focuses on upgrading the drainage system to improve road functionality and longevity. The main objective in providing road side drains is to Prevent water accumulation and reduce road surface deterioration, enhance road safety by minimizing skidding and hydroplaning risks.

Provision under this sub-head has been made for construction of Pipe Line Drain along main carriageway with collection chambers at 50 m intervals. RCC side drains are provided at existing and newly constructed Service road reaches.

5.3.7 Street Lighting

Efficient street lighting is essential for road safety, security and urban aesthetics. This proposal focuses on upgrading street lighting infrastructure to enhance visibility, reduce energy consumption, and to aid overall mobility on the project road. The street lighting proposal includes installation new street lighting illuminating both Main Carriageway and service road, however shifting of existing utility is not considered in the project proposal.

5.3.8 Traffic Sign, Markings and Other Safety Appurtenances

Traffic signs, road markings and safety appurtenances play a vital role in guiding road users, improving traffic discipline and reducing accidents. This proposal focuses on upgrading and installing necessary safety infrastructure to enhance road safety and efficiency. Proper traffic signs were selected at required locations along the project corridor. Centre line and edge markings along with Raised Pavement Markers required from safety point of view were considered in the project improvement proposal.

I. **Improvement / Maintenance During Construction**

II. **Carriageway Improvements / Maintenance:** The **Carriageway Improvements / Maintenance** proposals include provision for maintenance of existing pavement during construction. This primarily includes pothole filling, replacement of wearing course as and when required ensuring smoother & safer travel. The proposal focuses on maintaining the functionality of the existing pavement during construction.

III. **Drain Improvements / Maintenance:** The **Drain Improvements / Maintenance** proposals includes desilting of existing drain, repair and replacement of damaged cover slabs of existing RCC Drains.

IV. provision for maintenance of existing pavement during construction. This primarily includes pothole filling, replacement of wearing course as and when required ensuring smoother & safer travel. The proposal focuses on maintaining the functionality of the existing pavement during construction.

5.3.9 Footpath Improvements / Maintenance

maintaining the functionality of footpath is of prime importance to ensure safe movement of pedestrians during construction. Provision is made for repair, rectification of Footpath pavers, kerbs and other safety appurtenances is made in the project proposal.

5.4 PROPOSAL FOR PAVEMENT

5.4.1 Pavement Design

Pavement Design is the key aspect in any road construction project. In this section the details of the pavement design methodology, design parameters considered, and the designed pavement composition are described in detail. Traffic studies and pavement evaluation studies have been made use of in preparing this report.

For the project improvement, At Grade Main Carriageway is proposed with White Topping, whereas Service Road and Approach Ramps are proposed with Flexible pavement. Both the designs are detailed in the subsequent paragraphs.

5.4.2 Design Methodology

The Design of flexible Pavement is made based on IITPAVE Analysis as explained in IRC 37-2018.The design of White Topping is made as per IRC SP 76-2015 "Guidelines for Conventional and Thin White Topping".

5.4.3 White Topping

It's proposed to provide white topping for at grade improvement of carriageways. For the design of white topping, pavement condition survey, pavement structural evaluation using Falling Weight Deflectometer test, and pavement thickness (bituminous layer) is ascertained from filed studies.

5.4.4 Design of Whitetopping Over Existing Flexible Pavement

White topping is defined as a Portland Cement Concrete (PCC) overlay constructed on the top of an existing bituminous pavement. Whitetopping is thus PCC resurfacing (overlay) as a rehabilitation or structural strengthening alternative on bituminous pavement.

a. Types of White topping

- Conventional Whitetopping: It consists of a PCC overlay of thickness 200mm or more (on the top of existing bituminous layer) which is designed and constructed without consideration of any bond between the concrete overlay and underlying bituminous layer.
- Thin Whitetopping (TWT): PPC overlay of thickness greater than 100 mm and less than 200mm is classified as Thin Whitetopping (TWT). The bond between the overlaid PCC and underlying bituminous layer is often a consideration but it is not mandatory.
- Ultra-Thin Whitetopping (UTWT): PCC overlay of thickness equal to or less than 100 mm is classified as Ultra-Thin Whitetopping (UTWT). Bonding between underlying bituminous layer and overlaid PCC layer is mandatory.

Table 5.9 : White Topping Comparison

Sl. No	Conventional White topping	Thin White topping	Ultra-Thin White topping
1	Thickness 200mm or More	Thickness between 100mm and 200mm	Thickness 100mm or less
2	No bond between concrete overlay and underlying bituminous layer	Bond between concrete overlay and underlying bituminous layer is often considered but not mandatory	Bond between concrete overlay and underlying bituminous layer is mandatory
3	Existing Bituminous layer is treated as a Sub Base like DLC	Minimum thickness of hot mix bituminous pavement is 75mm (excluding the milled thickness)	Minimum thickness of hot mix bituminous pavement is 75mm (excluding the milled thickness).
4	Most appropriate for asphalt pavements that are extensively deteriorated.	Extensive roughened surface should be avoided.	Condition of the Existing Pavement should be free from wide cracks and without material/ sub grade related problems.
5	Joints at spacing (4.0 to 4.5m)	Joints at shorter spacing (0.6m to 1.25m)	Joints at shorter spacing (0.6m to 1.25m)
6	It can be treated as normal rigid pavement.	Rural Roads, Medium to Moderate Heavy Volume Roads (SH, MDR, Low Traffic NH), Intersections, Minor Airport Pavements	Low Volume Roads, Parking Lots, Footpaths, Residential Streets, Shoulders, Intersections.
7		Allowable repetitions may be multiplied by 0.75 so that Fatigue should not exceed 100%	
8		Reduction of 35% in load induced stresses	Reduction of 45% in load induced stresses

b. Pavement Evaluation

The evaluation of the existing pavement is an essential part of any overlay design including conventional Whitetopping. Field evaluation typically consists of a visual distress survey, deflection testing using Falling Weight deflectometer and coring. Foundation support value (k) is key information for thickness design. The Subgrade support value (k) for the existing bituminous surface can be back calculated from the resilient modulus (MR). 'k' values to be used can be taken from deflection test on the existing bituminous surface or by determining 'k' value from load test on the Subgrade and thereafter using Correlation Charts.

c. Thickness Design Criteria

The design principle adopted for Conventional Whitetopping is similar to those of normal concrete pavements as provided in IRC:58 "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways" and IRC:15 "Standard Specifications and Code of Practice for Construction of Concrete Roads". Design of TWT and UTWT is as per IRC: SP: 76-2015. Determination of modified / effective / support modulus of Subgrade reaction (k). The correlation between CBR and 'k' value for the Subgrade as given in SP: use 76-2015 for the design.

Modified "k" value on the top of Bituminous pavement can be determined using the charts given in IRC: SP: 76-2015: "Tentative Guidelines for Conventional, Thin and Ultra-Thin Whitetopping". Two charts are given for correlation based on the existing bituminous pavement is atop of granular base or cement treated base.

Alternative method is by using Characteristic Deflection from BBD Studies (Here it is correlated by conducting FWD Studies) and is a Graphical method. In this "k" value can be determined based on the characteristic deflection obtained from correlation.

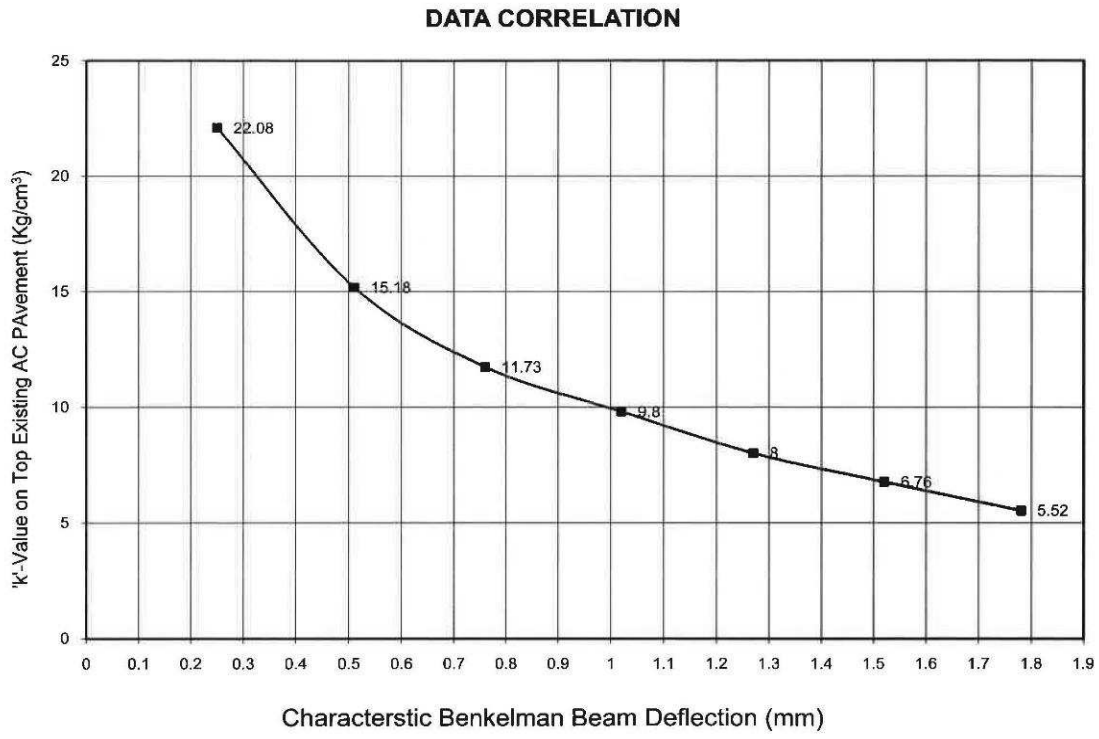


Figure 5.1 Graph showing relationship between Characteristic Deflection & Modulus of Subgrade reaction.

d. Surface Preparation

For Conventional Whitetopping, no special efforts are made to encourage bonding between the overlay and the underlying bituminous surface; however, some steps for surface preparations may be required to address existing restorations in the existing surface of the bituminous pavements or to correct surface profile. Three methods of surface preparation and overlying are normally used for Whitetopping.

Direct placement: The concrete overlay is placed directly on the existing hot bituminous surface after sweeping. Any ruts in the existing pavement are filled with concrete, resulting in a thicker concrete pavement in the rutted areas.

Milling: The existing bituminous surface is milled to obtain a uniform surface. Milling can be used to remove surface distortion like cracks in the top portion and adjust cross slopes. The removal of thickness should be between 25 to 50mm. Milling can also be selectively used with direct placement to treat the isolated stretch suffering from distortion in the project road. Milling is not mandatory.

Placement of Leveling course: Sometimes a leveling course of bituminous mix is used to produce a uniform surface for paving. A leveling course typically consists of minimum 50mm if Bituminous Macadam (BM). Exact quantity will depend upon the undulations.

When the distortion/rutting depth exceeds more than 50mm, the option of milling as an economical alternative may be evaluated.

Size of Slab (Spacing of Joint): As per IRC SP 76, square and short spacing joints are preferred, joints are to be provided at shorter spacing between 0.6 m to 1.25 m. also, by considering panel size less than 1.3 m we can nullify the effect of stresses due to tandem axle and consideration lower joint spacing will increase the number of joints which in turn reduce the driving comfort in a heterogeneous condition. Hence, an optimum joint spacing of 1.2m is adopted for Pavement Design.

Traffic for Pavement Design: The ADT of commercial vehicles viz Bus, LCV, and HCVs termed as CVPD is considered for pavement design. The design base year traffic is computed considering 2 years of construction period (from date of survey to completion of work and opening to traffic). Traffic Count is done in 2025 and considering four years of construction, the road is expected to be open to traffic by 2029, and it is considered as base year for pavement design. Assumptions made for traffic consideration includes 100% Buses will move at grade only. Whereas, 30% of Heavy Commercial Vehicles and 70% of Light Commercial vehicles will use the at grade facility. The traffic is projected at a rate of 7.5% per annum, the summary of ADT (maximum of 3 TVCs) is considered and projected base year traffic for pavement design is tabulated below.

Table 5.10 : Projected Base Year Traffic

Type	Mode	CVPD		
		Maximum Unidirectional Traffic	Traffic Considered for at Grade Movement	Adopted CVPD after Projection for Pavement Design
Goods	Std Bus	368	368	491
	LCV	1860	1302	1739
	2 Axle	655	197	263
	3 Axle	414	125	167
	MAV	204	62	83
Total Vehicles		3501	2054	2743

5.4.5 Design of White topping

1. Design Parameters		
i)	Design Life, years	20
ii)	Traffic Growth Rate. R	0.075
iii)	Commercial Traffic, cvpd	4079
iv)	Grade of Concrete, M40	40
v)	Cumulative Repetitions in 20 years	43356431
vi)	Design traffic (25% of (v)), cvpd	10839108

Table 5.11 : Percentages of Axle Load for the Design of TWT

Single Axle Load		Tandem Axle loads	
Axle load Class, Tons	% of Axle Loads	Axle load Class, Tons	% of Axle Loads
15-17	0.47		0.000
13-15	0.95	26-30	0.198
11-13	1.56	22-26	0.323
9-11	17.74	18-22	1.006
7-9	24.31	14-18	0.700
less than 8	50.48	less than 14	2.263
	95.51		4.49

Table 5.12 : Expected Repetitions for Axle Loads

Single Axle Load		Tandem Axle loads	
Axle load Class, Tons	% of Axle Loads	Axle load Class, Tons	% of Axle Loads
16	50605	28	21410
14	103155	24	35034
12	169331	20	108994
10	1922973	16	75907
8	2635330	less than 16	245238
less than 8	5471132		
	10352526		486582

Trial Thickness, cm	18
Subgrade Modulus, Kg/cm^{3,} k	9.25
Design Period, years	20
Modulus of Rupture, Kg/cm^3	45
Load Safety Factor	1
Length of Square Slab, cm	120
Modulus of Elasticity of concrete	300000
Poisson's ratio	0.15
Radius of relative Stiffness, cm l_c	63.37

Table 5.13 : Fatigue life Consumed for Single Axle Load

Axle Loads, Tonnes	Load Stress, Kg/cm²	Stress Ratio	Expected Repetition	Fatigue Life, N	Fatigue Life Consumed	Maximum load stresses, kg/cm2
16	23.4	0.52	50605	326000	0.16	23.45
14	20.5	0.46	103155	14335000	0.01	
12	17.6	0.39	169331	infinity	-	
10	14.7	0.33	1922973	infinity	-	
8	11.7	0.26	2635330	infinity	-	
less than 8			5471132	infinity	-	
					0.16	

Table 5.14 : Fatigue Life Consumed for Tandem Axle Load

Axle Loads, Tonnes	Load Stress, Kg/cm²	Stress Ratio	Expected Repetition	Fatigue Life, N	Fatigue Life Consumed
28	27.4	0.61	21515	23400	0.91
24	23.4	0.53	35206	229000	0.153
20	19.5	0.44	109529	infinity	0.000
16	15.63	0.35	76279	infinity	0.000
less than 16		0.00	246441	infinity	0.000
					1.07

The cumulative life consumed both by single and tandem axle is	**1.23**	
If the panel size is less than 1.30 m, then two axles of a tandem axle vehicle will not fall on the same panel simultaneously, hence, stresses should only be considered for single axle. The possibility of wheels of two adjacent vehicles Simultaneously placed on one panel is also excluded.		
The cumulative life consumed both by single and tandem axle is	**0.16**	**Thickness provided is Safe Against Fatigue Failure**

Table 5.15 : Temperature Curling Stresses:

$\sigma T = 1.933\text{-}241000(\alpha delT) + 1.267(L/l_e)$	
Δ T	-0.15°C/cm x Thickness of white topping overlay
Δ T, °C	-2.7
α	0.00001
Length of Square Slab, cm	120
Radius of relative Stiffness, cm l_c	63.37
σT, Kg/Cm²	**10.839**
Maximum load stresses, kg/cm²	**23.45**
Total flexural stresses due to load and curling = Maximum load stresses + curling stresses, kg/cm2	**34.29**

Slab is Safe against Stress
Design is Safe.

5.4.7 Recommendations for White Topping

The White Topping design for the project road is done based on the guidelines given in IRC: SP: 76-2015. The design tables indicate the design analysis summary with trial thickness of 17 cm and found safe for the project scenario of CVPD, Wheel Loads and Environmental condition with respect to fatigue criteria. However, considering the design life of 20 years for white topping and considering the polishing of concrete surface under wheel loads and as provision for retexturing of the pavement surface for maintaining skid resistance design White Topping Thickness is increased by 1cm and White Topping thickness of 18 cm is adopted / recommended for the project corridor. accordingly Recommended design white topping thickness with characteristic deflection is given below.

Table 5.16 : : Recommended White Topping Design Details

Sl. No.	Road Description	Characteristic Deflection, mm	Ex. BT Thickness, mm	k value, Kg/cm³	Design Thickness, cm
1	**Project Corridor Proposed with White Topping for At-Grade Improvement from** West of Chord Road to Outer Ring Road via Pipeline Road	1.10	160	9.25	**18**

5.4.7.1 Flexible Pavement Design for Project Corridor

The flexible pavement is proposed for the project corridor and has been designed based on the guidelines given in IRC: 37 – 2018. The design method is based on IIT Pave Analysis which considers effective modulus of the subgrade soil, resilient modulus of different layers of pavement, and traffic projected for design life in terms of million standard axles. For the project improvement, the approach ramps and newly constructed service roads are designed for 20 msa design traffic.

5.4.7.2 FLEXIBLE PAVEMENT DESIGN

The philosophy of pavement design involves designing pavements for satisfactory functional and structural performance of the pavement during its intended service life period. Roughness caused by variation in surface profile, cracking of layers bound by bituminous or cementitious materials, rutting (permanent or plastic deformation) of unbound/unmodified or partially modified subgrade, granular layers and bituminous layers are the primary indicators of the functional and structural performance of pavements.

The mechanistic-empirical design approach is used for the design of flexible pavements. The theory selected for the analysis of pavements is 'linear elastic layered theory' in which the pavement is modeled as a multi-layer system. Elastic modulus, Poisson's ratio and thickness of each layer are the pavement inputs required for calculation of stresses, strains and deflections produced by a load applied at the surface of the pavement. IITPAVE software has been used for the analysis of pavements.

The vertical compressive strain on top of the subgrade is considered to be the critical mechanistic parameter for controlling subgrade rutting. Horizontal tensile strain at the bottom of bituminous layer is taken as the causative mechanistic parameter which has to be limited to control bottom-up cracking in bituminous layers.

Rutting within bituminous layers caused by accumulated plastic (permanent) deformation in these layers due to repeated application of traffic loads is another major distress occurs in bituminous pavements. High pavement temperatures and heavy loads can cause early development of unacceptable levels of rut depth in bituminous mixes as the stiffness of the bituminous mix reduces at higher temperatures and the proportion of plastic (irrecoverable) deformation out of the total deformation will be larger under higher temperature and heavier loading conditions. To overcome these critical conditions and to ensure the satisfactory performance of bituminous pavements, pavement sections are selected in such a way to make sure the magnitudes of distresses are within acceptable levels during the service life period. The limiting stresses and strains are calculated based on the performance models adopted in the IRC guidelines for subgrade rutting, bottom-up cracking of bituminous layer and fatigue cracking of cement treated bases.

For the project corridor, the flexible pavement is designed for the combination of WMM and GSB Layers

5.4.7.3 PERFORMANCE CRITERIA

The following performance criteria are used as per IRC 37-2018 guidelines for the design of bituminous pavements.

A) Subgrade Rutting Criteria

An average rut depth of 20 mm or more measured along the wheel paths, is considered in the guidelines as critical or failure rutting condition. The equivalent number of standard axle load (80 kN) repetitions that can be served by the pavement, before the critical average rut depth of 20 mm or more occurs, is given by equations 1 and 2 respectively for 80 % and 90 % reliability levels.

$$NR = 4.1656 \times 10^{-08} [1/\varepsilon_V]^{4.5337} \quad \text{(for 80 \% reliability)} \quad (1)$$

$$NR = 1.4100 \times 10^{-08} [1/\varepsilon_V]^{4.5337} \quad \text{(for 90 \% reliability)} \quad (2)$$

Where,

NR	**subgrade rutting life (cumulative equivalent number of 80 KN standard axle loads that can be served by the pavement before the critical rut depth of 20 mm or more occurs)**
ε_V	**vertical compressive strain at the top of the subgrade calculated using linear elastic layered theory by applying standard axle load at the surface of the selected pavement system**

IITPAVE software is used for the analysis of pavements. For the computation of stresses, strains and deflections in the pavement, thicknesses and elastic properties (elastic modulus and Poisson's ratio) of different layers are the main inputs.

Considering, the project corridor is a Major Road, and the adopted design traffic of the project corridor is 20 msa, maximum allowable vertical strain on top of the subgrade is calculated from Equation (2) for 90% reliability in accordance with IRC 37 – 2018. computed maximum allowable vertical strain at the top of the subgrade using **equation (2)** is tabulated below in **Table 5.16.**

B) The occurrence of fatigue cracking (appearing as interconnected cracks), whose total area in the section of the road under consideration is 20 % or more, than the paved surface area of the section, is considered to be the critical or failure condition. The equivalent number of standard axle (80 kN) load repetitions that can be served by the pavement, before the critical condition of the cracked surface area of 20 % or more occurs, is given by equations 3 and 4 respectively for 80 % and 90 % reliability levels. The following equations recommended to calculate the maximum allowable horizontal tensile strain as per IRC 37 are reproduced below.

$$N_f = 1.6064 \times C \times 10\text{-}04\ [1/\varepsilon t]3.89 \times [1/MRm] \times 0.854 \text{ (for 80 \% reliability)} \quad (3)$$

$$N_f = 0.5161 \times C \times 10\text{-}04\ [1/\varepsilon t]3.89 \times [1/MRm] \times 0.854 \text{(for 90 \% reliability)} \quad (4)$$

Where,

$$C = 10^M, \text{ and } M = 4.84\left(\frac{V_a}{V_a+V_{be}} - 0.69\right)$$

Va	=	per cent volume of air void in the mix used in the bottom bituminous layer
Vbe	=	per cent volume of effective bitumen in the mix used in the bottom bituminous layer
Nf	=	fatigue life of bituminous layer (cumulative equivalent number of 80 kN standard axle loads that can be served by the pavement before the critical cracked area of 20% or more of paved surface area occurs)
εt	=	maximum horizontal tensile strain at the bottom of the bottom bituminous layer (DBM) calculated using linear elastic layered theory by applying standard axle load at the surface of the selected pavement system
MRm	=	resilient modulus (MPa) of the bituminous mix used in the bottom bituminous layer, selected as per the recommendations made in these guidelines.

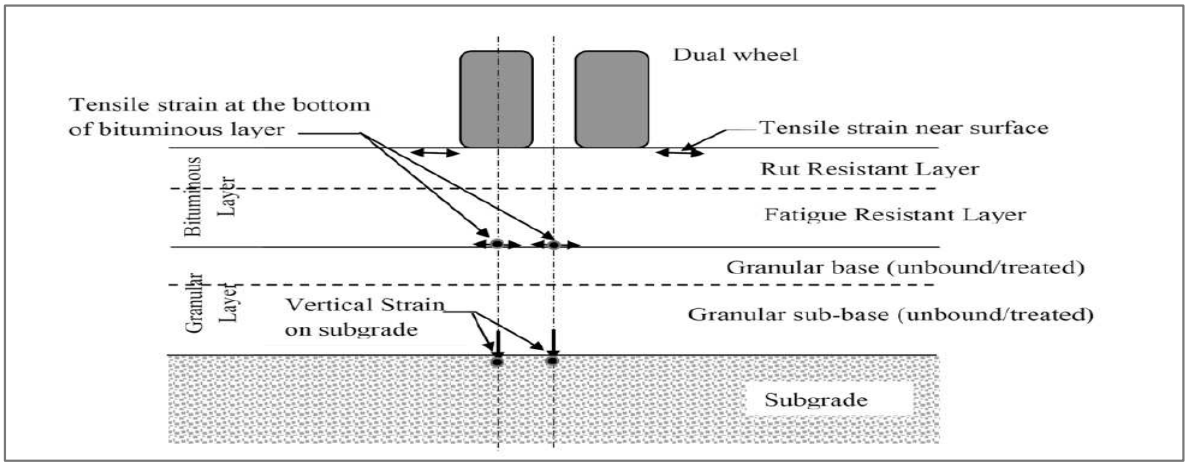
The factor 'C' is an adjustment factor used to account for the effect of variation in the mix volumetric parameters (effective binder volume and air void content) on the fatigue life of bituminous mixes.

Considering, the project corridor is a Major Road, and the adopted design traffic of the project corridor is 20 msa, maximum allowable horizontal tensile strain at the bottom of the bituminous layer is calculated from, Equation (4) for 90% reliability in accordance with IRC 37 – 2018. computed maximum tensile strain at the bottom of Bituminous layer using **equation (4).**

C) Flexible Pavement Design with Granular Base and Granular Subbase Layers

A flexible pavement is modelled as an elastic multilayer structure. Stresses and strains at critical locations are computed using a linear layered elastic model. Tensile strain, **(Et),** at the bottom of the bituminous layer, and the vertical subgrade strain, **(Ev),** on the top of the subgrade are conventionally considered as critical parameters for pavement design to limit cracking and rutting in the bituminous layers and non-bituminous layers respectively. The computation of stresses and strains at critical locations are made by using stress analysis software IIT PAVE.

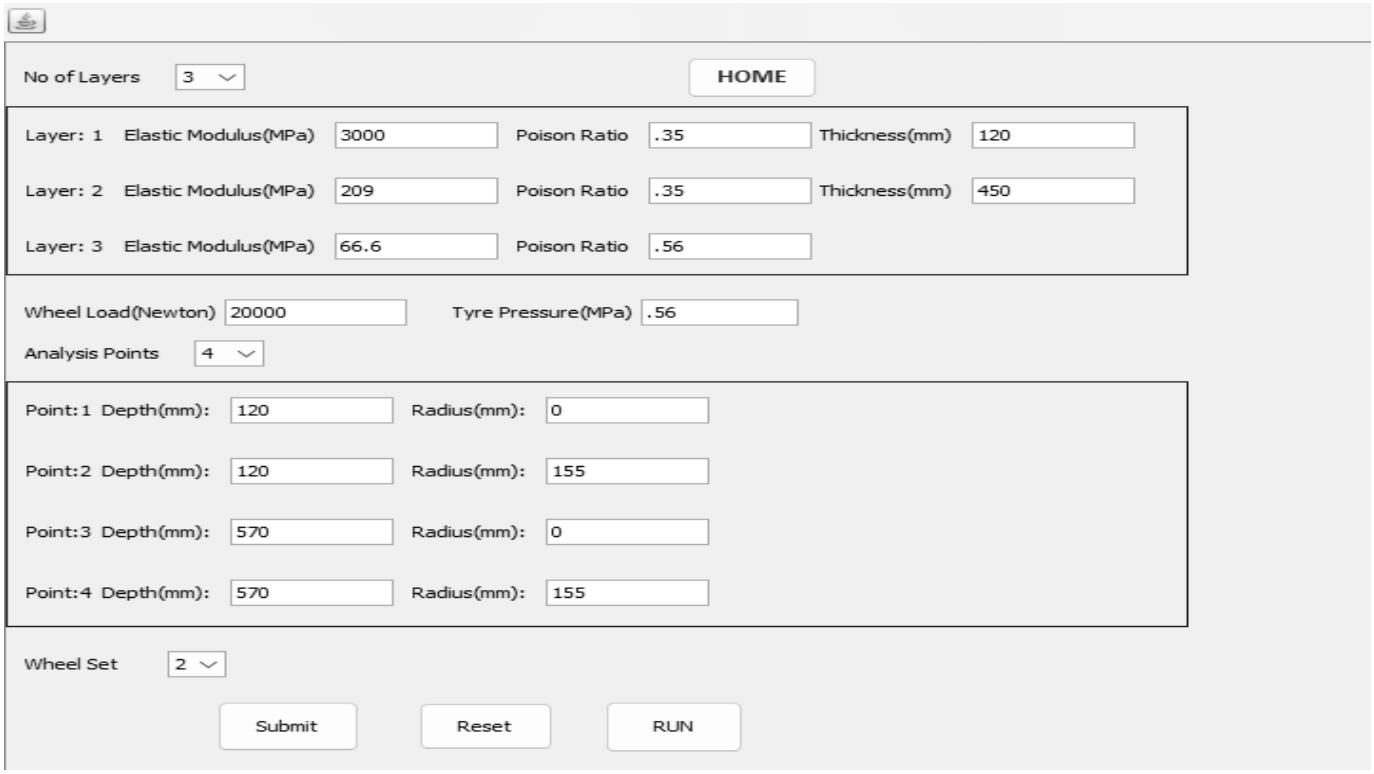
As discussed above, the strains were calculated at the following critical locations indicated in the figure, using IITPAVE software. Maximum value of the strain is adopted for design.



Granular Subbase layer showing the Locations of Critical Strains/Stresses

The maximum allowable critical strains at critical locations shown in the figure are compared with the critical strain values computed from IITPave for the pavement thickness considered. the pavement section is safe, if obtained strain values are lesser than the maximum allowable strains. The input data used and the output from the IIT

Pave software have been shown in the following screen shots for ready reference. The Summary of Flexible Pavement Design with Granular Base and Granular Subbase Layers is tabulated in **below table.**



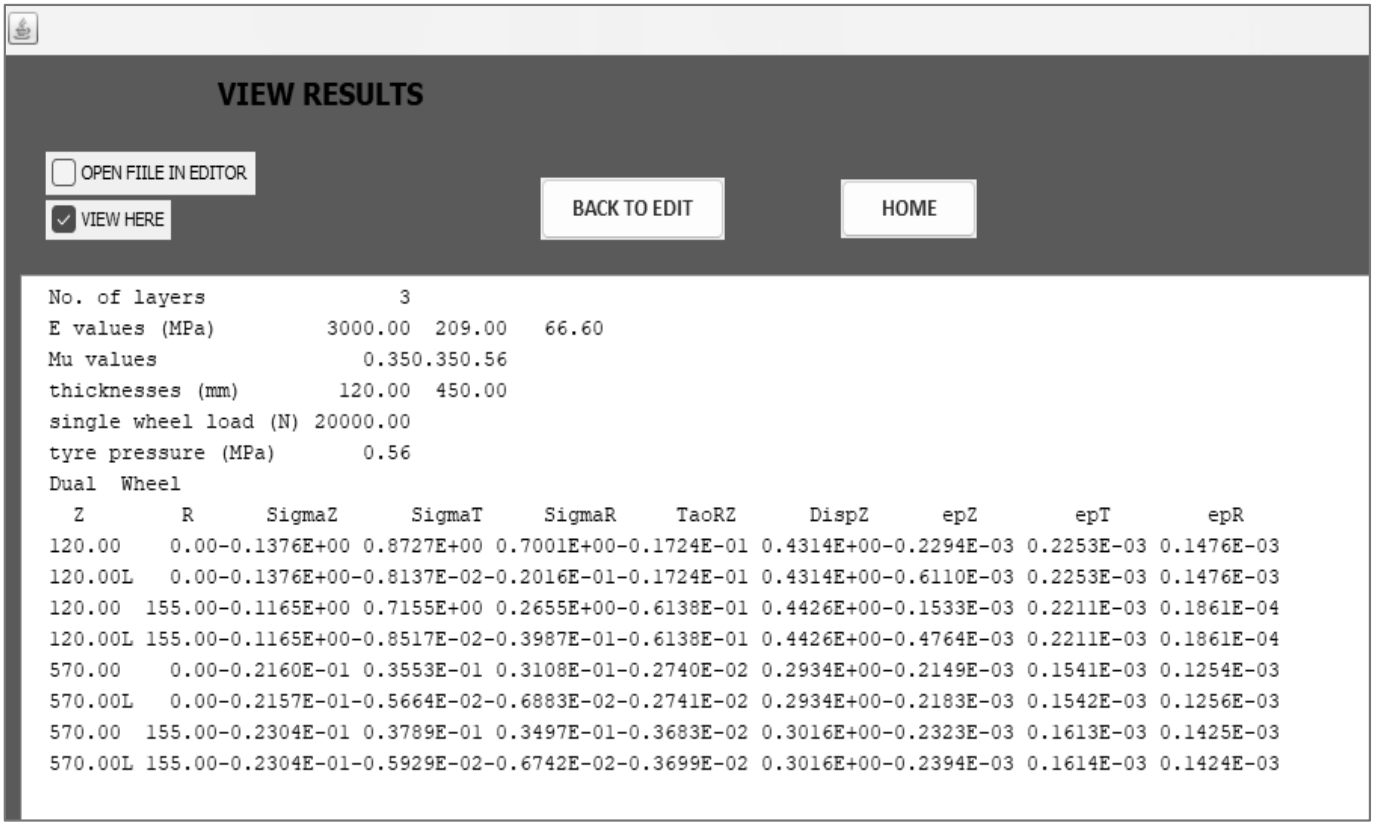


Figure 5.3 IITPave Input and Output Screenshot of Flexible Pavement Design with Granular Base and Granular Subbase Layer

Table 5.17 : Summary of Flexible Pavement Design with Granular Base and Granular Subbase Layers

Sl No	Description	Values
1	**Design Traffic, msa**	**20**
2	Allowable Maximum Horizontal Tensile strain below BT Layer, micro strain	225.4
3	Allowable Vertical compressive strain above Subgrade, micro strain	301.9
	Pavement Layers	**Trial thickness, mm**
4	Bituminous Concrete (BC), mm	40
5	Dense Bituminous Macadam (DBM), mm	80
6	Wet Mix Macadam (WMM), mm	250
7	Granular Subbase (GSB), mm	200
8	**Total Pavement Crust Thickness, mm**	**570**
	IITPave Analysis Output	
9	Obtained Horizontal Tensile strain below BT Layer, Micro strain	225.3
10	Obtained Vertical compressive strain above Subgrade, Micro strain	239.4
11	**Design w.r.to Obtained Maximum Horizontal Tensile strain**	**Design is Safe**
12	**Design w.r.to Obtained Vertical compressive strain**	**Design is Safe**

5.5 PROPOSED CROSS SECTIONS

Lane width, shyness, median width and overall width of each cross section proposed are derived from IRC: SP: 90 and IRC: 86, ensuring compliance with design standards for urban elevated facilities. The adopted widths are as follows:

Elevated Road:

- The lane width shall be 3.5 m
- The shyness shall be 0.5 m
- Paved Shoulder shall be 1.50m
- The median width shall be 0.610m for New Jersey Crash barrier.
- The total width of 4 lane elevated corridor is will be 19.61m
- both the left-hand side (LHS) and right-hand side (RHS) outer edges.

At Grade Road:

- The lane width shall be 3.0/3.5 m
- The shyness shall be 0.25/0.5 m
- The service lane shall be 5.5/7.5 m

Accordingly, the elevated corridor and split flyover have been planned as 4-lane access-controlled facilities, with configuration tailored to projected traffic flows and location-specific requirements of entry and exit ramps. The above standards will be consistently applied during detailed geometric design to ensure operational efficiency, safety, and compliance with IRC norms. The Typical Cross-Sectional Drawings are given in the Drawing Volume.

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CHAPTER 6. PROJECT COSTING

6.1 GENERAL

The project cost estimates have been prepared based on various items of works required for the construction of elevated corridor from **West of Chord Road to Outer Ring Road via Pipeline Road** within Bengaluru Metropolitan Region. The details of the proposed improvements are given in the below table **Table 6.1**

Table 6.1 :Summary of Proposed Improvements along the Project Corridor

Sl No.	Description	Total Length in m
1	Length of Main Carriageway	1580
2	Length of Roundabout (Junctions)	
3	Length of Split CW Section	
4	Length of Ramps Section (MCW)	400
5	Length of Curved Section	
6	Length of Taper section	
7	Length of Down ramp	
8	Length of up ramp	
9	Length of Viaduct ramp (Up and Down)	
10	Length of Up & Down ramp	
11	Length of Connecting Road	
Total		**1980**

The project adopts an advanced **Ultra High Performance Fiber Reinforced Concrete (UHPFRC) Superstructure** with a combination of **Strut & Tie Box** arrangements. which has been analysied in terms of technical feasibility, durability, and lifecycle costs, and the respective cost estimates have been worked out accordingly.

The project costs include not only the construction costs but also provisions for Preliminaries & General Works, Maintenance During Construction, Land Acquisition and Utility Relocation Costs. The estimates have been derived based on a detailed Bill of Quantities (BoQ) prepared from preliminary engineering designs of the proposed roads and structures.

For roadway components, quantities such as earthwork, embankments, and pavements have been calculated using the proposed cross-sectional drawings and pavement composition details. For specialized works, including bridges, structural components, and miscellaneous facilities, the quantities have been established through detailed design computations and manual verification, ensuring robustness and reliability. This comprehensive approach ensures that the cost estimates are realistic, technically sound, and inclusive of all critical project dimensions.

6.2 ITEMS OF WORK

The items of works are grouped under the following headings as detailed below in **Table 6.3**:

Table 6.2 : Details of Items of works

Sl. No	Description of work	Items of work
1.	Site Preparation & Clearance	➢ Clearing and grubbing, removal of existing obstructions ➢ Dismantling of existing pavement / structures (PCC / RCC / masonry / utilities)
2.	Earthwork & Foundations	➢ Earthwork excavation for foundations in all types of soil and rock ➢ Dewatering and disposal of unsuitable material ➢ PCC levelling course for foundations ➢ Bored cast-in-situ RCC piles including socketing in hard rock/Soil/Weathered Rock/Soft Work ➢ Pile caps including RCC and reinforcement ➢ Pile load tests and integrity tests ➢ Steel liners for Piles ➢ Excavation and disposal of unsuitable materials.
3.	Substructure Works	➢ Construction of Abutment piers and piers (RCC in varying heights) ➢ Construction of Precast PSC Abutment/Pier caps ➢ TMT reinforcement for Abutment piers and pier/ c Pier caps ➢ HT Strands for Pier Caps

Sl. No	Description of work	Items of work
4.	Superstructure Works	➢ PSC Girders, UHPFRC Strutted Box precasting and erection ➢ High tensile steel strands for prestressing ➢ Bearings (POT–PTFE / spherical) ➢ RCC Pedestal & TMT Reinforcement ➢ Expansion joints and asphaltic plug joints
5.	Approach & Ramps	➢ Construction of solid ramps / reinforced soil walls ➢ Approach slabs and gap slab(RCC) ➢ Embankments with selected borrow / excavation material ➢ Crash barriers on approaches, ramps & viaducts
6.	Road & Pavement Works	➢ At-Grade Main Carriageway for Project Corridor i. Pavement Quality Concrete (PQC – White Topping / Rigid Pavement) ii. Dry Lean Concrete (DLC) as base layer ➢ Service Roads, Up & Down Ramps and At Grade Improvements at Project Corridor iii. Granular sub-base (GSB) (at new Pavement) iv. Wet Mix Macadam (WMM) (at new Pavement) v. Dense Bituminous Macadam (DBM) vi. Bituminous Concrete (BC)
7.	Drainage & Protection Works	➢ RCC / PVC drainage pipes and spouts ➢ Catch pits, gully pits and inlet chambers ➢ Stone pitching and turfing for embankment protection ➢ Geosynthetics and anti-carbonation coating for durability
8.	Lighting, Utilities & Miscellaneous Works	➢ Road lighting system for corridor, ramps and service roads ➢ Utility shifting and provision of ducts

Sl. No	Description of work	Items of work
		➢ Road signage, pavement markings and gantry sign boards ➢ Crash barriers, guard rails and safety appurtenances ➢ Roofing / deck sheeting in split flyover or critical locations (if applicable) ➢ Painting of Structural members and Crash Barriers
9.	Specialized Tests & Miscellaneous	➢ Load testing of precast girders (PSC / UHPFRC) ➢ Non-destructive tests for piles and structural members ➢ Transportation and erection of precast girders/segments/piercaps ➢ Third-party testing and certification
10.	Project Facilities & Safety	➢ Intelligent Traffic Management System (ITMS) & Traffic Signals ➢ Bus shelters, landscaping and tree plantation in project influence zone

6.3 SPECIFICATIONS

The specifications adopted for arriving at the item rates for estimating the project cost conform to the provisions made in the Ministry of Road Transport & Highways (MoRT&H) "Specifications for Road and Bridge Works," Fifth Revision. In addition, provisions from the Indian Roads Congress (IRC) Codes, Bureau of Indian Standards (BIS), and specific guidelines issued by the Government of Karnataka have been followed wherever applicable.

6.4 COMPUTATION OF QUANTITIES

The quantities for various items of work have been computed as detailed below:

- Quantities for subgrade, sub-base, base, bituminous and rigid pavement courses were derived from the proposed cross-sections of service roads, ramps, and carriageway.

- Quantities for structures such as piers, pier caps, girders, bearings, crash barriers, etc., were calculated based on preliminary General Arrangement Drawings (GADs), span arrangements, and design calculations.

- Quantities for drainage, protection works, and utilities were computed based on the proposed layouts, engineering drawings, and standard provisions.

- Quantities for special items such as anti-carbonation coating, ATMS systems, and architectural finishes have been included as per DPR provisions.

6.5 UNIT RATES

Rate analysis has been carried out considering the Schedule of Rates (SoR) 2024–25, Public Works Department, Karnataka (Bengaluru Circle), duly incorporating the latest issue rates of cement, steel, bitumen, and fuel as notified by the Government of Karnataka.

Wherever the SoR did not provide rates for specialized items (such as bored piling in hard rock, precast UHPFRC girders, and ATMS systems), the rates have been adopted based on ongoing works of BMRCL, Metro Projects, and recent tendered rates in Bengaluru.

6.6 PROJECT COST

The project cost estimate has been prepared based on the scope of works for the proposed elevated corridor project,

Proposed Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout).

- Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC) Superstructure: Comprising Fiber Reinforced Concrete, Strut-and-Tie and Box Sections, offering enhanced durability, reduced maintenance requirements, and superior life-cycle performance.

The total project cost includes Construction Cost, Preliminaries & General Works, Maintenance During Construction, Land Acquisition and Utility Relocation Costs. A detailed breakup of costs, is presented in below tables **Table 6.3**.

Table 6.3 :Summary of Cost Estimate

Sl. No.	Items	Amount (In Rs)
1	Excavation for foundation	14,48,637.94
2	Foundation	77,97,17,490.50
3	Substructure	24,23,60,735.67
4	Super structure	1,47,59,34,802.68
5	Re walls approaches	3,56,57,474.89
6	At-grade improvement	42,88,65,547.34
7	Lighting	1,81,73,365.74
8	Preliminaries and general works	6,25,71,678.27
	Sub Total -A	**3,04,47,29,733.03**
9	Design charges @ 1.00% (For the amount sl.No 1 to Sl.No 8)	3,04,47,297.33
10	Maintenance during construction	8,53,32,951.86
	Sub Total -B	**11,57,80,249.19**
11	Maintenance charges for stand alone projects like Bridges/Tunnels/Flyover work; The Contractor shall be paid at 0.25% of the contract price, each for the remaining period of 5 years on total of items as per MorTH LTR No: RW/NH-37010/4/2010-EAP (Printing) Vol-IV, Government of India, Minitry of Road Transport and Highways dated: 05.03.2019 at model agreement page no.76 under section 14.1D	
12	for first 5 years @ 0.25%	3,80,59,121.66
13	for 5-10 years @ 0.50%	7,61,18,243.33
	Sub Total -C	**11,41,77,364.99**
	Amount put to tender (APT- A+B+C), Rs.	**3,27,46,87,347.21**
	GST @ 18%	58,94,43,722.50
	Total Civil Cost, Rs.	**3,86,41,31,069.71**
i	Provision for Contingencies and Provision for Departmental Establishment Charges @ 1% on APT	3,27,46,873.47
ii	Provision for Independent Engineer / PMC @ 1.50% on APT (Including GST)	5,79,61,966.05
iii	Provision for Price escalation @ 5.0% for the 2nd year i.e., 0.5% of APT (Including GST)	9,66,03,276.74
iv	Provision or utility shifting at 8% of APT (Including GST)	30,91,30,485.58
v	Provision for Arboriculture/ Afforestation @ 0.50% on APT (Including GST)	1,93,20,655.35
vi	Land Acquisition Cost including structures/TP	50,99,05,673.10
vii	Miscellenous and other Department Deposits	2,00,000.00
	Total Project Cost	**4,89,00,00,000.00**

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CHAPTER 7. CONCLUSIONS & RECOMMENDATIONS

7.1 PROJECT DEVELOPMENT

The present project has been conceptualized and developed in consultation with the **Bengaluru Smart Mobility Infrastructure Limited (B-SMILE)**, with the primary objective of strengthening urban connectivity and easing congestion along the northern and eastern sectors of Bengaluru city. The project proposal comprises the construction of elevated corridor from **West of Chord Road to Outer Ring Road via Pipeline Road.**

The project corridor traverses through one of the busiest urban environments in the country, characterized by rapid growth in vehicular population, limited road width, and severe traffic bottlenecks at major junctions. Unlike conventional highway development in rural or semi-urban areas, this project is **entirely urban in nature**, requiring careful integration of the proposed elevated structures with existing roadways, flyovers, railways, utilities, metro infrastructure, and highly built-up surroundings.

The proposals were carried out considering the minimum land acquisition, reducing social impacts, and optimizing traffic dispersal at major junctions. Based on stakeholder consultations and technical analysis, UHPFRC Superstructure is worked out for project improvement proposal:

- Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC) Superstructure with Strut & Tie Box Sections.

UHPFRC has been analysed in terms of technical feasibility, construction methodology, durability, cost implications, and long-term serviceability. The Project proposals include elevated corridor from West of Chord Road to Outer Ring Road. Project corridor is designed to provide grade separation at highly congested intersections and ensure seamless integration with the larger elevated network.

The Project corridors pass through rapidly developing urban and peri-urban area, including West of Chord Road, where traffic demand already exceeds existing capacity.

Accordingly, the **Draft Detailed Project Report (DDPR)** has been prepared, incorporating engineering design, cost estimates based on **PWD Karnataka SoR 2023-24 (Bengaluru Circle)**, and consideration of alternative structural systems. The project development has been undertaken with the intent of delivering a technically robust, socially responsive, and environmentally sustainable solution to Bengaluru's mobility challenges.

Table 7.1 : Summary of Proposed Improvements along the Project Corridor

Sl.	Parameter	West of Chord Road to Outer Ring Road
1	Length of Main Carriageway	1580
2	Length of Roundabout (Junctions)	
3	Length of Split CW Section	
4	Length of Ramps Section (MCW)	400
5	Length of Curved Section	
6	Length of Taper section	
7	Length of Down ramp	
8	Length of up ramp	
9	Length of Viaduct ramp (Up and Down)	
10	Length of Up & Down ramp	
11	Length of Connecting Road	
	Total length of Improvement-Elevated	**1980**
	Total length of Improvement-At-grade	**2100**

7.2 EXPECTED PROJECT BENEFITS

The proposed elevated corridor represents a strategically significant urban transport intervention aimed at decongesting Bengaluru's arterial road network and strengthening north-south as well as east-west connectivity across the northern and eastern zones of the city. By providing continuous, access-controlled elevated facilities connecting West of Chord Road, the project will act as a high-capacity mobility framework, easing pressure on existing corridor. This intervention is expected to deliver substantial reductions in travel time, smoother traffic dispersal, and enhanced road safety while improving economic efficiency.

The project's benefits will extend well beyond mobility gains. With the provision of a dedicated elevated corridor, fast-moving through-traffic will be segregated from local traffic at-grade, thereby improving the reliability and efficiency of public transport services such as BMTC buses. Reduced idling and smoother traffic flow will directly translate into lower vehicle operating costs, reduced consumption of fuel and lubricants, and a measurable reduction in vehicular emissions, contributing to improved air quality

and lower noise levels in densely developed northern Bengaluru. Signal-free junctions along the alignment will further reduce delays and enhance commuter convenience.

From a socio-economic perspective, the corridors are expected to act as a catalyst for urban renewal and balanced growth. Improved accessibility and connectivity will stimulate commercial activity in adjacent localities, attract investment into retail, logistics and service sectors, and generate large-scale employment both during construction and in the post-implementation phase through enhanced business opportunities. Faster and more reliable access to workplaces, markets, educational institutions, and healthcare facilities will contribute to improved productivity, public welfare, and quality of life for citizens.

The project also integrates modern safety and community-friendly features including continuous pedestrian footpaths at-grade, pedestrian guardrails and crossings, anti-crash barriers, advanced drainage systems to prevent waterlogging, LED-based illumination, landscaping, and urban design elements to improve the overall corridor environment. With safer pedestrian movement and faster emergency response enabled by congestion-free roads, the project is expected to lower accident rates and strengthen public safety.

Overall, the proposed elevated corridors are expected to transform mobility patterns in north–south as well as east–west sectors across the northern and eastern zones of the Bengaluru, decongest key arterial routes, promote sustainable economic activity, and enhance the city's competitiveness as a global innovation and investment hub.

7.3 TRAFFIC ANALYSIS

Comprehensive Traffic Volume Counts (TVCs) were undertaken at strategic locations along the proposed elevated corridors to capture prevailing demand, traffic composition, and operational performance. The classified data, collected in both directions, was analyzed to determine peak-hour traffic, capacity utilization, and Level of Service (LOS) performance.

The capacity assessment carried out at classified TVCs along the alignment TVC-01 (near Shiva Temple), shows that peak-hour volumes are already at or very close to the practical planning capacity of a 4-lane urban arterial elevated facility (≈3,600 PCU/h two-way) in the opening year (2025). Computed V/C ratios for 2025 are approximately 0.95 (TVC-01), deteriorating rapidly under the conservative 5% annual traffic growth assumption. By the

near-term horizon all three TVCs are projected to operate at LOS-E/F, with peak-period queuing and breakdown expected at critical merge/weave locations.

The alignment traverses highly built-up urban areas, with multiple intermediate junctions and relatively short inter-junction spacings, ranging from less than 300 m to about 4,000 m, averaging roughly 1,200 m. These short spacings, coupled with frequent turning movements and pedestrian/cross-traffic interactions, constrain the effective throughput of the at-grade facility and cause repeated breakdowns in traffic flow. Experience shows that localized junction improvements or isolated flyovers only shift bottlenecks downstream, offering limited and short-term relief in such dense corridors.

Traffic growth projections, based on a conservative 5% annual increase, confirm that the already saturated conditions will worsen significantly in the design horizon years, with rapid deterioration in corridor speeds, recurring queuing, and high vehicle operating costs. The analysis clearly establishes that the existing 4-lane network is inadequate to serve current and future demand, thereby necessitating the development of a continuous, access-controlled elevated corridor to restore acceptable service levels, provide reliable travel times, and ensure long-term corridor efficiency.

7.4 IMPROVEMENT PROPOSALS

7.4.1 Alignment

Project alignment improvement proposal comprises the design of project elevated corridor aimed at strengthening the road network, easing congestion, and improving mobility in the northern and eastern parts of Bengaluru. The project includes Elevated Corridor from **West of Chord Road to Outer Ring Road Corridor (2.20 km)**, extending from West of Chord Road (Ch. 0+000) to Outer Ring Road (Ch. 2+850) via Mahalakshipuram, Nagapura, and Basaveshwaranagar, where improvements are confined from 0+000 to Ch. 2+200 section, owing to an ongoing grade separator construction; Together, these corridor provide seamless grade-separated linkages between major arterial routes and peripheral growth areas, reducing travel delays and enhancing accessibility to emerging urban and regional hubs.

7.4.2 Proposed Cross Sections

Lane width, shyness, median width and overall width of each cross section proposed are derived from IRC: SP: 90 and IRC: 86, ensuring compliance with design standards for urban elevated facilities. The adopted widths are as follows:

Elevated Road:

- The lane width shall be 3.5 m
- The shyness shall be 0.5 m
- Paved Shoulder shall be 1.50m
- The median width shall be 0.610m for New Jersey Crash barrier.
- The total width of 4 lane elevated corridor is will be 19.61m

At Grade Road:

- The lane width shall be 3.0/3.5 m
- The shyness shall be 0.25/0.5 m
- The service lane shall be 5.5/7.5 m

Accordingly, the elevated corridors have been planned as 4-lane access-controlled facilities, with configuration tailored to projected traffic flows and location-specific requirements of entry and exit ramps. The above standards will be consistently applied during detailed geometric design to ensure operational efficiency, safety, and compliance with IRC norms

7.4.3 Improvement Proposals

The project proposal comprises elevated corridor strategically planned to enhance and improve access to the airport influence zone while easing congestion on parallel arterial routes in Bengaluru. The West of Chord Road to ORR Corridor (2.20 km) are planned as short but critical interventions, integrating with ongoing works and major junctions to streamline traffic flow. Collectively, these interventions are expected to reduce conflicts at major intersections, provide signal-free travel, and establish a high-capacity elevated network complementing the city's arterial and sub-arterial road system.

The elevated carriageway has been designed as a 4-lane facility with 3.5 m lanes, 0.5 m shy distance, and 1.5 m paved shoulders, ensuring adequate operational safety. At-grade lanes are standardized at 3.0 m width with 0.25/0.5 m shy distance, reflecting Tender SURE and BBMP urban standards. Horizontal alignment has generally adhered to design speeds of 60/80 km/h with minimum curve radii of 150 m, while constrained locations

necessitated reduced radii, with adequate design justification. Vertical geometry has been optimized to maintain safe sight distances and operational efficiency.

To balance accessibility with minimal land acquisition, ramps of 4.5 m width with protective crash barriers are provided only at strategically required locations, coordinated with tunnel entry/exit points. Restoration measures include provision of a 1.8 m minimum footpath-cum-drain wherever land available/required, smoothened junction entry/exit curves, modern street lighting, signage, and pavement markings, thereby improving local-level traffic flow.

The project incorporates multiple superstructure systems tailored to site conditions and span requirements:

- PSC I-Girders for regular spans,
- PSC Box Girders for medium spans,
- UHPFRC Strutted Box Sections for high durability and reduced depth,
- Steel Composite/ Girders for obligatory longer spans and rail/metro crossings.

UHPFRC Superstructure were specifically developed for cost:

UHPFRC superstructure with strut-and-tie box sections, enabling longer spans with fewer piers, ideal for constrained urban junctions and crossings.

UHPFRC Superstructure were assessed for constructability, long-term serviceability, and cost implications using PWD Karnataka SoR 2023–24 (Bengaluru Circle). For the proposed elevated corridor, 50 m UHPFRC strut-and-tie box spans were evaluated, with the 50 m UHPFRC span system recommended owing to its superior structural efficiency, reduced pier footprint in constrained urban conditions, and enhanced durability.

The corridor integrates a comprehensive suite of safety and serviceability features including New Jersey crash barriers (0.61 m median), High Containment Crash Barrier, edge protection systems, utility corridors/ducts at 500 m spacing to prevent repeated road cutting, and ITMS (Intelligent Traffic Management Systems). Pedestrian safety is addressed through redesigned bus stops (at disturbed location), with noise barriers proposed at sensitive urban stretches. The combined implementation of the Elevated Corridors will provide a high-capacity, signal-free arterial linkage across north–south as well as east–west sectors across the northern and eastern zones of the Bengaluru. With robust geometric standards, carefully designed ramps, integrated at-grade improvements, hybrid structural systems, and advanced safety and ITMS provisions, the project ensures

long-term durability, congestion relief, and sustainable urban mobility. It is strongly recommended to proceed with the current proposal, adopting a 50 m UHPFRC spans, thereby balancing economy, constructability, and service performance in line with forecasted traffic demand.

7.5 PAVEMENT

For the project improvement, At Grade Main Carriageway is proposed with White Topping, whereas Service Road and Approach Ramps are proposed with Flexible pavement. The Design of flexible Pavement is made based on IITPAVE Analysis as explained in IRC 37-2018.The design of White Topping is made as per IRC SP 76-2015 "Guidelines for Conventional and Thin White Topping".

The summary of recommended pavement thickness for the particular sections is presented here in Table below.

Table 7.2 :Recommended White Topping Design Details for at grade Improvement

Sl. No.	Road Description	Characteristic Deflection, mm	Ex. BT Thickness, mm	k value, Kg/cm³	Design Thickness, cm
1	**Project Corridor Proposed with White Topping for At-Grade Improvement from** West of Chord Road to Outer Ring Road via Pipeline Road	1.10	160	9.25	**18**

Table 7.3 : Proposed Flexible Pavement Composition for Service Roads and Approach and Entry / Exit Ramps

Sl No	Description	Values
1	**Design Traffic, msa**	**20**
2	Allowable Maximum Horizontal Tensile strain below BT Layer, micro strain	225.4
3	Allowable Vertical compressive strain above Subgrade, micro strain	301.9
	Pavement Layers	**Trial thickness, mm**
4	Bituminous Concrete (BC), mm	40
5	Dense Bituminous Macadam (DBM), mm	80
6	Wet Mix Macadam (WMM), mm	250

Sl No	Description	Values
7	Granular Subbase (GSB), mm	200
8	**Total Pavement Crust Thickness, mm**	**570**
IITPave Analysis Output		
9	Obtained Horizontal Tensile strain below BT Layer, Micro strain	225.3
10	Obtained Vertical compressive strain above Subgrade, Micro strain	239.4
11	**Design w.r.to Obtained Maximum Horizontal Tensile strain**	**Design is Safe**
12	**Design w.r.to Obtained Vertical compressive strain**	**Design is Safe**

7.6 PROJECT COST

The project cost estimate has been prepared based on the scope of works for the proposed elevated corridor project, which includes:

Elevated Corridor from West of Chord Road to Outer Ring Road via Pipeline Road (Nandini Layout).

- Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC) Superstructure: Comprising Strut-and-Tie Box Sections, offering enhanced durability, reduced maintenance requirements, and superior life-cycle performance.

The total project cost includes Construction Cost, Preliminaries & General Works, Maintenance During Construction, Land Acquisition and Utility Relocation Costs. A detailed breakup of costs, is presented in below tables **Table 7.4**.

Table 7.4 : Summary of Cost Estimate

Sl. No.	Items	Amount (In Rs)
1	Excavation for foundation	14,48,637.94
2	Foundation	77,97,17,490.50
3	Substructure	24,23,60,735.67
4	Super structure	1,47,59,34,802.68
5	Re walls approaches	3,56,57,474.89
6	At-grade improvement	42,88,65,547.34
7	Lighting	1,81,73,365.74
8	Preliminaries and general works	6,25,71,678.27
	Sub Total -A	**3,04,47,29,733.03**
9	Design charges @ 1.00% (For the amount sl.No 1 to Sl.No 8)	3,04,47,297.33
10	Maintenance during construction	8,53,32,951.86
	Sub Total -B	**11,57,80,249.19**
11	Maintenance charges for stand alone projects like Bridges/Tunnels/Flyover work; The Contractor shall be paid at 0.25% of the contract price, each for the remaining period of 5 years on total of items as per MorTH LTR No: RW/NH-37010/4/2010-EAP (Printing) Vol-IV, Government of India, Minitry of Road Transport and Highways dated: 05.03.2019 at model agreement page no.76 under section 14.1D	
12	for first 5 years @ 0.25%	3,80,59,121.66
13	for 5-10 years @ 0.50%	7,61,18,243.33
	Sub Total -C	**11,41,77,364.99**
	Amount put to tender (APT- A+B+C), Rs.	**3,27,46,87,347.21**
	GST @ 18%	58,94,43,722.50
	Total Civil Cost, Rs.	**3,86,41,31,069.71**
i	Provision for Contingencies and Provision for Departmental Establishment Charges @ 1% on APT	3,27,46,873.47
ii	Provision for Independent Engineer / PMC @ 1.50% on APT (Including GST)	5,79,61,966.05
iii	Provision for Price escalation @ 5.0% for the 2nd year i.e., 0.5% of APT (Including GST)	9,66,03,276.74
iv	Provision or utility shifting at 8% of APT (Including GST)	30,91,30,485.58
v	Provision for Arboriculture/ Afforestation @ 0.50% on APT (Including GST)	1,93,20,655.35
vi	Land Acquisition Cost including structures/TP	50,99,05,673.10
vii	Miscellenous and other Department Deposits	2,00,000.00
	Total Project Cost	**4,89,00,00,000.00**